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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

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MECHANICAL AND PHYSICAL SCIENCE,

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JULY, 1865.

CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

General Problem of Trussed Girders. By DE VOLSON WOOD, Prof. C.E., University of Michigan.

Concluded from page 317, vol. xlix.

In the latter part of the preceding article I found the position of the neutral axis when the resistances of the fibres are directly proportional to their distance from the neutral axis. We will now proceed to find it according to Barlow's theory.

b. Let there be two laws of resistance. According to one let the resistances vary directly as the distance from the neutral axis; and according to the other let the resistance be the same on each unit.

1. Let the moduli of elasticity be equal. Then will the resistances to *direct* elongation or compression be equal at equal distances from the neutral axis.

Using the notation before given, and we have $\frac{\mathrm{S}}{d_t} = \frac{\mathrm{C}}{d_c} = s =$ the resistance of a unit of fibres at a unit's distance from the neutral axis to *direct elongation or compression.* I speak of DIRECT resistances because the *longitudinal shearing* is not included.

Hence, $s\int_0^{d_t} zy\,dy =$ the *direct* resistance to tension,

$$s\int_0^{d_c} zy\,dy = \text{the } \textit{direct} \text{ resistance to compression,}$$

and since $\int_0^{d_t} z\,dy$ is the total area which is subjected to tension, we have

$\varphi\int_0^{d_t} z\,dy =$ the resistance to longitudinal shearing on the side of tension.

$\varphi\int_0^{d_c} z\,dy =$ the resistance to longitudinal shearing on the compressed side.

Hence the first of equation (61) becomes

$$s\int_0^{d_t} zy\,dy + \varphi\int_0^{d_t} z\,dy - s\int_0^{d_c} zy\,dy - \varphi\int_0^{d_c} z\,dy = 0,$$

$$\text{or } s\int_{d_c}^{d_t} zy\,dy + \varphi\int_{d_c}^{d_t} z\,dy = 0. \quad . \quad . \quad . \quad (99).$$

Example.—Let the beam be rectangular; b the breadth, and d the depth.

Then we have

$$sb\int_{d-y}^{y} y\,dy + \varphi b\int_{d-y}^{y} dy = 0,$$

$$\text{or } \tfrac{1}{2}s\left[y^2-(d-y)^2\right] + \varphi\left[y-(d-y)\right] = 0,$$

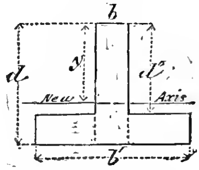
$$\therefore y = \tfrac{1}{2}d,$$

or the neutral axis coincides with the centre of the sections.

If the horizontal plane which is passed through the middle of the depth, divides the beam into two equal and symmetrical parts, then will the neutral axis lie in this plane, for the longitudinal shearing will be the same in the two parts, and hence the second term of (99) will be zero, and the equation reduces to equation (87), which shows that the neutral axis passes through the centre of the sections, which, in this case, is at half the depth. Hence the neutral axis passes through the centre of beams having circular, elliptical, or regular polyginal sections, double T or H sections with equal flanges, and tubular girders in which the hollow is similar to the full section. But it does not pass through the centre of triangular or single T beams, or other non-symmetrical forms.

EXAMPLE.—To further illustrate the use of equation (99), I will apply it to a single T, Fig. 35. Using the notation as given in the figure, and equation (99) will give for the part above the neutral axis

FIG 35



$$\tfrac{1}{2}s\,by^2+\varphi\,by \quad . \quad . \quad (100).$$

To find it for the lower part we suppose that the vertical web passes through the flanges to thebot tom; hence we have for the lower part of the web,

$$\tfrac{1}{2}s\,b(d-y)^2+\varphi\,b(d-y) \quad . \quad . \quad (101).$$

According to the 4th principle, as stated in the preceding article, page 310, the longitudinal shearing stress in the flanges is $\frac{d'}{d-y}\varphi$. The width of both flanges is $b'-b$. Hence, for the sum of all the forces in the flanges we readily find

$$\tfrac{1}{2}s(b'-b)\left[(d-y)^2-(d''-y)^2\right]+\frac{d'}{d-y}\varphi\left[(d-y)-(d''-y)\right](b'-b),$$

$$\text{or } \tfrac{1}{2}s\,(b'-b)\,(d'd+d'd''-2d'y)+\varphi(b'-b)\frac{d'^2}{d-y} \quad . \quad . \quad (102).$$

Substitute (100), (101), and (102) in the first of (61), and it gives

$$\tfrac{1}{2}s\,by^2+\varphi\,by-\tfrac{1}{2}s\,b(d-y)^2-\varphi\,b(d-y)-\tfrac{1}{2}s\,(b'-b)(d'd+d'd''-2d'y)-\frac{\varphi(b'-b)d'^2}{d-y}=0,$$

from which y may be found.

2. Let the moduli of elasticity be unequal. In this case, the direct strain, $y\,s$, brings into play the elastic resistance; hence, for this strain we proceed as in the preceding theory; but the expression for the longitudinal shearing will be exactly of the same form as in the preceding case, or $\varphi\int_{d_c}^{d_t} z\,dy$.

3. *To find the position of the neutral axis so as to give a minimum strength.*

This is equivalent to making the second member of equation (84), or $\frac{s\,\mathrm{I}}{d_1}+\varphi\iint y\,dy\,dx$, a minimum. As I have not succeeded in reducing this to a more definite form, dependent upon the form of section, I am obliged to reduce it for each special case. To show how to treat it, I will apply it to rectangular beams. As before, let b be the breadth, and d the depth, and $\mathrm{I}=\iint y^2\,dy\,dx$. Then we have

$$\frac{s}{y}\int_0^b\int_{-(d-y)}^{y} y^2\,dy\,dx+\varphi\int_0^b\int_0^y y\,dy\,dx+\varphi\int_0^b\int_0^{d-y} y\,dy\,dx=$$

minimum.

$$\text{Or, } \frac{b\,\text{s}}{3y}(d^3-3d^2y+3dy^2)+\frac{\varphi b}{2}\left(y^2+(d-y)^2\right)=\text{minimum}, \qquad . \ (103)$$

$$\therefore\ y^3+\frac{\text{s}-\varphi}{2\varphi}y^2=\frac{\text{s}}{6\varphi}d^3,$$

from which y may be found. If $\varphi=\text{s}$, as it does very nearly for cast iron beams having solid sections, we find

$$y=0{\cdot}54958d, \text{ or } 0{\cdot}04958d$$

from the centre of the section. Comparing this result with that found under the former hypothesis, (see Example 1, which follows equation (94),) and we see that the neutral axis is nearer the centre of the beam at the instant of rupture, according to this hypothesis, than according to the former. If φ be zero, equation (103) will give the same result as (94). If φ be very large compared with s, or $\text{s}=0$, equation (103) gives $y=\frac{1}{2}d$; hence, we infer *that all positive values of φ makes the neutral axis nearer the centre of the beam than if it were zero.* The same general principles are applicable to beams of any form.

B. *Suppose that the deflecting forces are inclined to the axis of the beam.*

a. Adopt the common theory, and let the moduli be unequal.

Let φ be the angle which the direction of force makes with the axis of the beam.

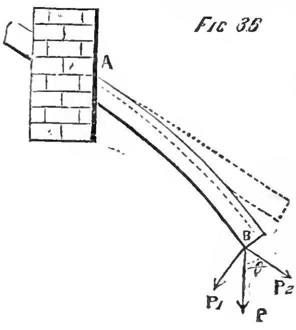


FIG 35

Then resolving the force normally and perpendicularly to the axis of the beam, and we have,

For the former, $\text{P}_1=\text{P}\sin\theta$;

For the latter, $\text{P}_2=\text{P}\cos\theta$.

The former tends directly to deflect the beam, while the latter tends, in this case, to elongate it.

Proceeding as in the preceding article, page 314, and we find,

For the total resisting forces to tension,

$$\frac{c\,\text{E}_t}{dx}\int\!\!\int_0^{d_t} y\,dy\,dx;$$

for the total resisting forces to compression,

$$\frac{c\,\text{E}}{dx}\int\!\!\int_0^{d_c} y\,dy\,dx,$$

and these in the first of (59) give,

$$\frac{c\,\text{E}_t}{dx}\int\!\!\int_0^{d_t} y\,dy\,dx-\frac{c\,\text{E}_c}{dx}\int\!\!\int_0^{d_c} y\,dy\,dx=\text{P}\cos\theta \qquad . \ (105).$$

The similarity of the triangles O L N and N e k, Fig. 31, and equation (89) give $c=\frac{d}{y}=\frac{dx}{\rho}$, which, in (105) gives

$$E_t \iint_0^{d_t} y\,dy\,dx - E_c \iint_0^{d_c} y\,dy\,dx = \rho P \cos\theta \qquad (106).$$

The exact reduction of (106) is somewhat difficult, but as we have before observed E_t nearly equals E, and practically may be considered exactly equal, and as this hypothesis simplifies the equation, we

2. *Suppose that the moduli are equal.*

Then equation (106) becomes,

$$\iint_0^{d_t} y\,dy\,dx - \iint_0^{d_c} y\,dy\,dx = \frac{\rho}{E} P \cos\theta \qquad (107).$$

Let K = the area of the section.

$\bar{Y}$ = the distance from the neutral axis (the origin of co-ordinates) to the centre of gravity of the sections.

Then, from mechanics we have

$$K\bar{Y} = \iint_{''}^{''} y\,dy\,dx = \iint_0^{d_t} y\,dy\,dx - \iint_0^{d_c} y\,dy\,dx\,;$$

hence, (107) becomes

$$\bar{Y} = \frac{\rho P}{E K} \cos\theta \qquad . \qquad . \qquad . \qquad (108).$$

Since ρ and θ are variable when the beam is curved, we see that the neutral axis is not parallel to the axis of the beam.

If $\theta = 90°$; $\bar{Y} = 0$.

If $\theta = 0$; ρ is infinite and $\bar{Y} = \infty$.

22°. *Let the direction of the force coincide with the axis of the bar.*

We shall then have $\beta = \gamma = 90°$; $\alpha = 0°$ or $180°$ according as the bar resists tension or compression; $b = c = 90°$, $a = 180°$ or $0°$ according as the force is tensive or compressive; and equations (4) and (5), vol. xlviii, page 231, gives

$$\Sigma F = \Sigma P.$$

The resistance ΣF may be expressed in terms of the elastic resistances, or the ultimate resistance. For the former we have the well known expression $\Sigma F = E K \dfrac{\lambda}{l}$; in which E is the modulus of elasticity, K the section, λ the elongation, and l the length. For the latter $\Sigma F =$ $S K$ or $C K$, in which K is the transverse section, and S the modulus of strength, and C the modulus of resistance to crushing. We have thus come out at the equation which forms the starting point of most writers on the resistance of materials. My aim has not been to exhaust any part of the subject, but rather to show the *general* relation and dependence of the equations used in computing the strains on the several parts of a bridge, and the strains on the fibres of beams, by deducing all of them from the fundamental equations of statics.

In some cases I have reduced the equations so as to make them applicable to special cases, while in others they would require consid-

erable transformation. Of the former I might mention the parabolic arched truss; and of the latter, normally pressed arcs and some conditions for maximum shearing; but inasmuch as they are all statical problems, the equations which are applicable to them must be deducible from the equations which I have given. I might also have considered some problems in which we should determine the distribution of the parts so as to fulfil certain conditions which might be assigned to the strains. Such problems may properly form independent articles.

Some errors have crept into the work, most of which will be readily detected by the reader. I have noticed the following:

ERRATA.

Vol. xlviii, page 232, line 6, for $\Sigma P(\cos b - y \cos a)$ read $\Sigma P(x \cos b - y \cos a)$.
" " " line 14, for $\sin \beta$ read $\sin \alpha$.
" " 309, line 11, for $V_0 \, x \, {}_1 \Sigma$ read $V - \Sigma_0 \, x \, {}_1 - P$.
" " 378, line 18, for $H \, D$ read $H_1 D$.
" " " bottom line, for P^x read P_x.
" " 379, line 5, for $\cos = \theta$, &c., read $\cos \theta =$.
" " 380, line 20, for Jone's read Jones'.
" " 381, line 12, for $\Sigma_0 \, x \, {}_\theta \, P$ read $\Sigma_0 \, x \, P$.
" " 383, line 13, for $x = -\frac{w}{r}$ read $x = -\frac{wL}{r}$.

On the Size of Pins for connecting Flat Links in the Chains of Suspension Bridges. By Sir CHARLES FOX.

From the London Artizan, May, 1865.

In the construction of chains of this kind, it is of the highest importance that the pins which pass through and connect together the links of which the chains are composed should be of the right size, inasmuch as their being too small, as compared with the links through which they pass, renders ineffective a portion of the iron contained in the latter, which then exists only as a useless load to be carried by such links; while, at the same time, if the pins and heads of the links be too large, they become uselessly cumbersome and expensive.

Careful examination and experiments made upon a large scale (which will be explained hereafter) have brought out facts by which a simple rule has been arrived at—a rule that may safely be adopted as a guide in deciding upon the relative sizes of these two parts.

On this rule mainly depends the economical use of iron in the construction of such chains.

In this paper the term chains for suspension bridges implies such as are usually employed, and are composed of several flat bars of equal thickness throughout, placed side by side, but having their ends swelled edgeways, so as to form what are technically termed heads, and which are coupled together by pins passing through holes in such heads, as shown in Figs. 5 and 6 of the accompanying drawing.

In deciding upon the size of the pins it has often been assumed as a close approximation, that, as about the same force is required for

shearing as for breaking wrought iron by extension, it would be necessary to give the pin a cross section equal to the sectional area of the smallest portion of the link only. The fact of the possibility of links being torn and destroyed by the pin being too small to present the necessary bearing surface, althougth quite large enough to resist the calculated shearing force brought to bear upon it by the links, seems hitherto not to have attracted notice ; but as the strength of a chain depends upon the proper extent of surface being offered by the pins of the links to pull against, such a mode as the one described has been proved by experiment to be altogether fallacious. For by this mode

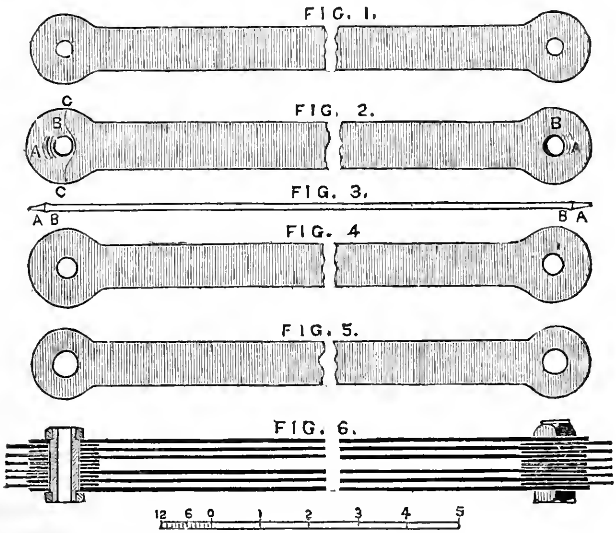


Fig. 1. Link for Kieff Bridge. Depth of head, $16\frac{1}{2}$ inches, of centre, $10\frac{1}{4}$ inches diameter of hole, $4\frac{1}{2}$ inches.

Fig. 2. Elevation, showing result of proof.

Fig. 3. Section through centre, showing result of proof.

Fig. 4. Experimental link, with wider head. Depth of head, $18\frac{1}{2}$ inches, diameter of hole, $4\frac{1}{2}$ inches.

Fig. 5. Link with properly proportioned hole for pin. Depth of head, $17\frac{1}{2}$ inches, diameter of hole, $6\frac{1}{2}$ inches.

Fig. 6. Plan of chain and section of pin and links.

of estimating, the size of a pin passing through links 10 inches wide and of uniform thickness (that is, not having the head thicker than the body of the link) would be something less than $3\frac{1}{2}$ inches in diameter, whereas (as will presently be shown) in order to get the whole benefit from such a link, the pin must be somewhat more in diameter than 6 inches, and for the following reasons :

In wrought iron the initial forces necessary to extend or diminish by compression the length of a bar are practically the same ; and hence it arises that unless the surface of the pin on which the semi-cylindrical surface of the hole in the link bears is as great as the smallest cross section of the link itself, the head will be torn by the pin; and since

to provide this necessary surface it is essential to have a pin of much larger size, the question of its ability to resist the operation of shearing never arises, and the whole subject resolves itself into one of bearing surface.

If the pin be too small, the first result on the application of a heavy pull on the chain will be to alter the position of the hole through which it passes, and also to change it from a circular into a pear-shaped form, (*vide* Fig. 2,) in which operation the portions (A A, Figs. 2 and 3) of the metal in the bearing upon the pin become thickened in the effort to increase its bearing surface to the extent required. But while this is going on, the metal around the other portions (B B, Figs. 2 and 3) of the hole will be thinned by being stretched, until at last, unable to bear the undue strains thus brought upon it, its thin edge begins to tear, and will, by the continuance of the same strain, undoubtedly go on to do so until the head of the link be broken (or, rather, torn) through, no matter how large the head may be; for it has been proved by experiment that by increasing the size of the head, without adding to its thickness (which, from the additional room it would occupy in the width of the bridge, is quite inadmissible) no additional strength is obtained.

Acting upon the principle above described, most engineers have made the pins of their chains far too small, whereby much money has been wasted by making the links of a size, and consequently of a strength, of which it was, through the smallness of the pins, impossible to obtain the full benefit. Indeed, to such an extent has this been carried, that in one of the most noted suspension bridges hitherto constructed, a very large sum has been thrown away upon what is worse than wasted material, inasmuch as that material, remaining as load only, has to be carried by the chains, and correspondingly weakens the structure.

I am also acquainted with a very recently constructed suspension bridge, in which some of the links, which are 10 inches wide, have the holes in their heads but 2 inches, instead of $6\frac{1}{2}$ inches, in which case more than two-thirds of the iron in the links is useless.

The first time my attention was seriously called to this important subject was when Mr. Vignoles entrusted my late firm of Fox, Henderson & Co. with the manufacture of the chains of the great suspension bridge for carrying a military road over the Dnieper at Kieff, which was constructed by him for the Russian government.

As the chains for this bridge weighed upwards of 1600 tons, upon which the expense of transport was very heavy, they having to be shipped to Odessa, and thence carted over very bad roads for upwards of 300 miles to Kieff, it was considered of the first importance to ascertain whether or not they were well proportioned; and accordingly a proving machine was specially prepared, of power sufficient to pull into two any link intended to be used on this bridge.

These links, as shown in the drawing attached to the contract, (see Fig. 1,) were, for convenience of transit, but 12 feet long from centre to centre of pin-holes, $10\frac{1}{4}$ inches wide by 1 inch thick in their body

or smallest part, with a head at each end also 1 inch thick, swelled out to $16\frac{1}{2}$ inches in width, so as to allow of holes for receiving pins $4\frac{1}{2}$ inches in diameter. The cross sectional area of these pins was 15·9 inches, or rather more than 50 per cent. in excess of the cross sectional area of the link at its smallest part.

According to the usual mode of ascertaining the size of these pins, by making them of such dimensions as to resist the force required to shear them, they possessed upwards of a third more section than was thus shown to be necessary. Still, in practice, a pin of this size proved altogether disproportionate to the size of the links, and required to be increased from $4\frac{1}{2}$ to $6\frac{1}{2}$ inches in diameter before it was possible to break a link in its body or narrowest part—fracture in every previous case taking place at the hole, and through the widest part of the head, as shown in Fig. 2.

The iron in the links for this bridge was of a very high quality, and was manufactured by Messrs. Thorneycroft & Co. from a mixture of Indian and other approved pig iron, and required a tensile strength of about 27 tons per sectional inch to break it, so that taking the narrowest part at, say 10 inches, a strain of 270 tons ought (had the size of the pin been in proper proportion) to have been required to pull it into two; instead of which, so long as the pins were but $4\frac{1}{2}$ inches in diameter, the head tore across (as shown at Fig. 2) at its widest part with about 180 tons, or two-thirds only of the strain desired and provided for, as far as the size of the body of the links was concerned.

This unexpected result led to the belief that the size of the heads was insufficient, and accordingly a few experimental links were prepared with their heads 2 inches wider than before (as shown in Fig. 4); but these nevertheless were found to require no additional force to tear asunder; hence it became obvious that fracture arose from some cause not yet ascertained.

As has already been stated, the rupture took place across the widest part of the head (C C, Fig. 2); but on attempting to adjust the piece broken off, to the position it originally occupied in the link, it was observed that while the fractured surfaces came in contact at the outside of the head, they were a considerable distance apart at the edge of the pin-hole. (See Fig. 2.)

This at once proved that during the application of the tension, which at last ended in producing fracture, the various portions of the head had been subject to very unequal strains; and upon careful examination, the rationale of this fracture became apparent from the consideration that the hole which originally was round had become pear-shaped, (see Fig. 2,) having altered its position, and that the iron of the link which, during the application of the load, bore upon the pin, and was consequently in a state of compression, had become considerably thickened in consequence, as was now evident, of an effort to obtain a greater bearing surface, (see A, Figs. 2 and 3,) while the other portion of the iron around the pin-hole, being subject to tension, had been so weakened and thinned by being stretched, as to cause a tearing action to take place, which, having once commenced, would obvi-

ously, by the continuance of the same strain, rend through the entire head, no matter what its width might be.

From this it was clear that any increase of size of the head (unless by thickening, which, as I have before stated, is inadmissible) was of no avail; and it was now that the principle which forms the subject of this paper became manifest, viz: that there was a certain area of semi-cylindrical surface of the hole having a bearing on the pin proportionate to the transverse section of the body or narrowest part of a link, and quite essential to its having equal strength in all its parts; and that any departure from this proportion could not fail to bring about either waste of iron in the body of the links, if the pin was of insufficient size to offer bearing surface, or waste of metal in the heads of the links and in the pins, if the latter were larger than necessary for obtaining this fixed proportion of areas.

Having arrived at this point, a link, similar in all respects to the previous one, with holes $4\frac{1}{2}$ inches in diameter, and which broke across the head with 180 tons, was taken, and its holes enlarged to 6 inches, but without increasing the width of the head, which still remained $16\frac{1}{2}$ inches; so that the only difference was the removal of an annular piece $\frac{3}{4}$-inch in width from the hole, and so making it 6 inches instead of $4\frac{1}{2}$ inches in diameter, thereby actually diminishing the quantity of iron in the head to this extent—when it was most interesting to discover that by this slight alteration, by which the semi-cylindrical surface bearing on the pin had been increased from 7·0 to 9·4 sectional inches, the power of the link to resist tension had increased in about the like proportion, having rendered a force of nearly 240 tons necessary to produce fracture.

From subsequent experience, it has become evident that had the pins of these chains increased to $6\frac{1}{2}$ inches diameters, giving a bearing surface of 10·2 square inches, the proper proportion between them and the body of the links would have been very nearly arrived at, while with those of only 6 inches in diameter about an inch of the body of the links was wasted.

The practical result arrived at by the many experiments made on this very interesting subject, is simply that, with a view to obtaining the full efficiency of a link, the area of its semi-cylindrical surface bearing on the pin must be a little more than equal to the smallest transverse sectional area of its body; and as this cannot, for the reasons stated, be obtained by increased thickness of the head, it can only be secured by giving sufficient diameter to the pins.

That as the rule for arriving at the proper size of a pin proportionate to the body of a link may be as simple and easy to remember as possible, and bearing in mind that from circumstances connected with its manufacture the iron in the head of a link is perhaps never quite so well able to bear strain as that in the body, I think it desirable to have the size of the hole a little in excess; and accordingly for a 10-inch link I would make the pin $6\frac{2}{3}$ inches in diameter, instead of $6\frac{1}{2}$ inches, that dimension being exactly two-thirds the width of the body, which proportion may be taken to apply to every case.

As the strain upon the iron in the heads of a link is less direct than in its body, I think it right to have the sum of the widths of the iron on the two sides of the hole 10 per cent. greater than that of the body itself. (See Fig. 5.)

As the pins, if solid, would be of a much larger section than is necessary to resist the effect of shearing, there would accrue some convenience, and a considerable saving in weight would be effected, by having them made hollow and of steel.

In conclusion, I would remark that my object in writing this paper has been, first, to call attention to the fact that a link is far more likely to be torn by the pin being too small, than a pin to be sheared by a link; and secondly, to try to establish a simple rule by which their proper comparative sizes may always be arrived at; and I have been induced to investigate this very important subject from having generally found in existing suspension bridge chains a wide departure from what is right in this respect, in having the pins far too small.

On the Wear and Tear of Steam Boilers. By Frederick Arthur Paget, Esq., C.E.

From the Journal of the Society of Arts, No. 649.

According to the published report of the engineer of the Manchester Boiler Assurance Company, forty-three explosions, attended with a loss of seventy-four lives, occurred in 1864 in this country. The engineer of the Midland Boiler Assurance Company gives the number as forty-eight, causing the deaths of seventy-five and the injury of one hundred and twenty persons. These statistics are confessedly incomplete, being, from obvious causes, numerically understated. The Royal Commissioners on the metallic mines report, that in the districts of Cornwall and Devon, boiler explosions are of very frequent occurrence;* and, in these sparsely populated districts, they easily escape the public attention. Explosions, again, which only injure without killing outright, and therefore do not call for a a coroner's inquest, also happen without attracting much notice. The figures cited thus understate the destruction and injury to life through boiler explosions, while only a guess can be hazarded as to the annual loss of property they cause. Each explosion testifies to the probability that a number of boilers have been prevented from exploding by mere chance, as also to much unchecked decay and deterioration, which might have been prevented by greater care and more knowledge. Besides, apart from the disastrous results of an explosion itself, the undue wear and tear of boilers means the suspension of the workshop or factory and the demurrage of the steam vessel. With respect to the causes of explosions themselves, "there are," to use the words of the late Mr. Robert Stephenson,† "but few cases which do not exhibit undue weakness in some part of the boiler;" and

* Report of the Commissioners on the Metallic Mines. Presented to both houses of Parliament by command of Her Majesty, 1864, page 21.

† Proceedings of the Institution of Civil Engineers, 1856, page 281.

the same opinion appears to be held by Prof. Faraday.* The opinion that an explosion is rather due to the weakness of the boiler than to the strength of the steam may, in fact, be said to be universal. There is, indeed, a very complex train of mechanical, chemical, and physico-chemical forces, leading to the deterioration and consequent destruction of a steam boiler, and it is probable that no other metallic structure is subjected to such complicated conditions. The pressure of the steam and the heat of the fire produce mechanical effects, while both the burning fuel and the water react chemically on the plates and in accordance with their varying chemical properties. Each of these agents play, so to speak, into the other's hands, furthering and quickening the other's progress. It is difficult to distinguish with strictness between the effects of each; and it is mainly for the sake of convenient examination that they be classified into—1. The effects of the pressure of the steam; 2. the mechanical effects of the heat; 3. the chemical effects of the fuel; 4. the chemical effects of the feed-water.

The Direct Effects of the Pressure of the Steam.

In calculating the working strength of a cylindrical boiler, the plates are assumed to be under a static load, and to be submitted to a tensile strain. The former of these assumptions is seldom, and the second is never correct. There are two principal causes that tend to exert impulsive strains on the sides of a boiler: 1. The sudden checking of the current of steam on its way from the boiler to the cylinder; 2. quick firing, attended with too small a steam room; and both may sometimes be found to act in combination. To the first of these causes the explosion, for instance, of one of the boilers of the *Parana* steamer, at Southampton, a few years ago, has been ascribed by the Government engineer surveyor;† to the second, the explosion of the copper boiler of the *Comte d'Eu* yacht, in France. According to Dr. Joule, the mere dead pressure of an elastic fluid is due to the impact of its innumerable atoms on the sides of the confining vessel. When the motion of a current of steam is suddenly checked, as by the valve, in its passage from the boiler to the cylinder, its speed and weight cause a recoil on the sides of the boiler analogous to the effects of the, in this case, almost inelastic current of water in the hydraulic ram;‡ this action is necessarily most felt with engines in which the steam is let on suddenly, as in the Cornish, and other single-acting engines, working with steam valves, suddenly affording a wide outlet, and as suddenly closing. It produces such phenomena as the springing or breathing of cylinder covers, and the sudden oscillations of gauges, noticed long ago by Mr. Josiah Parkes and others.§ Some years ago while standing on a boiler working a single-acting engine, and with a deficient amount of steam room, the writer noticed the boiler to slightly breathe

* Proceedings of the Institution of Civil Engineers, 1852, page 392.

† Rudimentary treatise on Marine Engines and Steam Vessels, etc. By Robert Murray, C.E., Engineer Surveyor to the Honorable Board of Trade, pages 74–78.

‡ Instituto di Scienze. Milano, 1829.

§ Transactions of the Institution of Civil Engineers. Vol. iii.

with every pulsation of the engine. The same action has been observed by others with boilers, the steam room of which is out of proportion to their heating surface. The intensity of the instantaneous impulses thus generated would be, as Mr. Parkes observes, difficult to measure, but their repeated action must readily affect the boiler at its mechanically weakest points. The more or less sudden closing of a safety-valve while the steam is blowing off would evidently produce the same effect; and this view is strengthened by the fact that the great majority of locomotive boilers—in which while at work there is no such sudden call on the reservoir of steam as in the Cornish engine—explode while standing with steam up at the stations.* It is not denied that, in the case of a locomotive, the mere extra accumulation of steam from the safety-valves being screwed down above the working pressure will also come into play. But there can be little doubt that most boilers are subjected, sooner or later, and with more or less frequency, to an impulsive load. This being the case, this consideration alone would demand a factor of safety of *six* in the designing of steam boilers. The Commissioners on the application of iron to railway structures, in their third conclusion on a mass of evidence which has made their investigations the most valuable ever conducted on the strength of materials, say, "that, as it has been shown, that to resist the effects of reiterated flexure, iron should scarcely be allowed to suffer a deflection equal to one-third of its ultimate deflection, and since the deflection produced by a given load is increased by the effects of percussion, it is advisable that the greatest load in railway bridges shall in no case exceed one-sixth of the weight which would break the beam when laid on at rest in the centre."†

Emerson showed, more than sixty years ago, that the stress tending to split in two an internally *perfectly* cylindrical pipe, submitted to the pressure of a fluid from the interior, is as the diameter of the pipe and the fluid pressure. He also showed "that the stress arising from any pressure, upon any part, to split it longitudinally, transversely, or in any direction, is equal to the pressure upon a plane drawn perpendicular to the line of direction." As in a boiler the thickness of the metal is small compared with the radius, the circumferential tension has been assumed to be uniformly distributed; and the strain per unit of length upon the transverse circular joint being only half that upon the longitudinal joints, the strength of the latter has been taken as the basis of the calculations for the tensile strength of the joints. But in taking the internal diameter of the boiler as the point of departure, the internal section has been assumed to be a correct circle, which would only be practically true in the case of a cylinder bored out in a lathe, and never in that of a boiler. Two of Emerson's corollaries from

* Reports of the Inspecting Officers of the Board of Trade, 1850-64. (The four locomotive boilers which burst last year all did so while standing. Neither the primary rupture leading to the explosions, nor the secondary rupture caused by the explosion, took place through the rivet holes.)

† Report of the Commissioners appointed to inquire into the Application of Iron to Railway structures. xviii.

his first proposition have, in fact, been neglected. He shows that if one of the diameters be greater than another, there will then be a greater pressure in a direction at right angles to the larger diameter, the greatest pressure tending to drive out the narrower sides till a mathematically true circle is formed. The second is that "if an elastic compressed fluid be enclosed in a vessel, flexible, and capable of being distended every way, it will form itself into a sphere."* A number of proofs can be adduced that both these influences are more or less at the bottom of the wear and tear caused by the direct action of the steam.

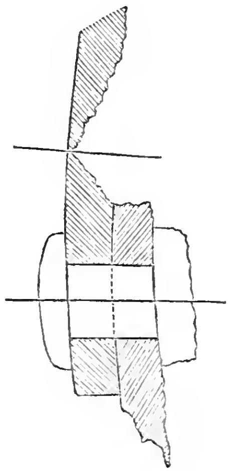
From 1850 to 1864 forty locomotive explosions, causing a loss of human life, have occurred in the United Kingdom. The Board of Trade reports in the Blue-books presented to Parliament, and more especially those by Captain Tyler, R.E., probably form the most valuable and connected series of records extant on boiler explosions. This is more especially the case with regard to wear and tear caused by the direct action of steam unmasked by the effects of the fire, as the barrel and outside fire-box of a locomotive cannot be said to be under the direct action of the heat. Perhaps the vibration of the boiler through the motion on the line may intensify this action, but it is clear that vibration cannot be a primary cause. The majority of the reports are illustrated by careful drawings. Eighteen of the forty boilers gave way at the fire-box—eleven from the crown of the inside fire-box being blown down upon the tube plates; seven from the shells or sides giving way. Twenty burst at the barrel; and two explosions may be ascribed to miscellaneous causes, from an originally defective plate, and from running off the line. Leaving out all those which occurred at the fire-box, as the majority of these might be ascribed to other influences than direct pressure, all the twenty explosions of the barrel could be traced either to internal furrows or to cracks, both running parallel with one of the longitudinal joints of one of the rings forming the barrel. All the joints which thus gave way were lap-joints; and the furrows or the cracks (and the former greatly preponderate in number) occur at the edge of the inside overlap, and, therefore, just at the point where the diminution of diameter caused by the lap-joint would be most affected by the pressure of the steam. (See Fig. 1.)

The plate at the channels shows distinct traces of lamination through the cross bending, and it is probable that plate of a good material will

* The action of a fluid pressing with equal forces in all directions can be evidently represented as to force and direction by innumerable radii of equal length led from a single point in all directions. Upon this principle may be explained the spherical shapes of soap bubbles, of the bulbs of thermometers, (blown while the glass was in a plastic state,) of the thin india rubber balls, used as playthings, and which are formed by forcing air into india rubber tubes closed at one end. Gas and air bubbles in water are necessarily flattened by the hydrostatic pressure. It is upon that principle that a gun of soft ductile iron often bulges out at the breech.

gradually laminate, while inferior metal will crack through in much less time. Nor are these furrows found with only lap-joints. Butt-joints, with a strip inside the boiler, and thus destroying the equilibrium of internal pressure, have been found to be attended with similar furrows. Channels of exactly the same character have been observed in locomotive boilers with lap-joints, which have exploded in Germany.*

Fig. 1.



(Half size cross section of the furrowed longitudinal joint in the fire box ring of a boiler which exploded at Overton station, on the 30th May, 1864. It does not differ from other furrows.)

Similar furrows, again, have been noticed in marine boilers, and in old boilers generally, longitudinal furrows being of course about twice as dangerous as those appearing transversely. The smoke-box tube-plates of inside cylinder-locomotive engines have been found to be similarly influenced by the racking action of the engines, showing furrows around the cylinder flanges. A parallel case is often found in Lancashire with the end-plates of double-flued Fairbairn boilers, which may have been too stiffly stayed to the barrel. Circular furrows, caused by the confined motion of the end-plates, are sometimes found at the base of the angle iron rings jointing the internal flues to the end-plates. But furrowing seems with no kind of boiler to be more felt than with locomotive boilers. This is due to the high pressure, to the thicker plates causing a coarser lap, and more especially to the fact that the unstayed barrel cannot be thoroughly examined without drawing the tubes, thereby enabling the furrow to enlarge itself unnoticed.

The inside fibres of a plate bent up while cold are necessarily initially in a state of compression. When the pressure from the inside comes on, striving to form a perfect cylinder, the plate gets bent to and fro by its own elasticity on one side, and by the pressure on the other. If the iron be brittle, it may crack right through ; if ductile, the outside fibres gradually lose their elasticity, and, necessarily aided by other causes, crack away. This action is progressive, and probably very rapid towards its later stages. Once a weak place formed itself it would have to do more and more of the work. Even when pulled by the direct tension of the testing machine, a lap-joint behaves in a somewhat similar way. For instance, a half-inch lap, solidly welded by Bertram's process, has only half the strength of the solid plate;† while the $\frac{3}{8}$-inch lap-weld has actually two-thirds of the strength of the entire plate.

Messieurs Jean Piedbœuf and Cie, of Aix-la-Chapelle, Düsseldorf, and Liege, who turn out annually upwards of one thousand steam

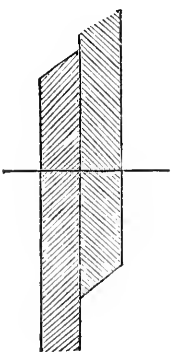
* Organ fuer die Fortschritte des Eisenbahnwesens. 1864, page 159.

† "Recent Practice on the Locomotive Engine," page 5.

boilers, use a lap-joint which probably gives slightly better results as to furrowing, while it is much easier to caulk, and must be therefore less injured by that process. (See Fig. 2.)

There is, however, another important appearance to be noted with respect to these furrows. An iron cylindrical vessel under internal pressure would, of course, rupture long before it could assume a spherical shape, from its ranges of elasticity and of ductility being so short. But it may be said to be undergoing three distinct stresses in as many directions. There is a stress acting on the ends, and tending to rupture the boiler in two halves in a direction parallel to the axis; there is the stress which is hoop tension in a true circle, but which acts with a cross bending strain in an ordinary boiler; and there is the stress which tends to make it assume the shape of a barrel, or to bulge it out in the centre of its length. The precise action on a material of several strains like this is a portion of the strength of materials which is still completely unknown. Its probable effects might be illustrated by the ease with which a stretched india rubber ring is cut through with a knife, or that with which a column under compression is broken by a blow from a hammer, or by the similar ease with which a tube under tension is split by a sharp blow; in fact, the operation of caulking a defective boiler under steam seems thus to often give it the finishing stroke which causes an explosion. The new boiler which burst from a defective plate at the Atlas Works, Manchester, in 1858, and that which burst through a crack at a longitudinal joint last January, at Peterborough, both gave way whilst being caulked. This again accounts for the fact that adjacent boilers sometimes explode one after the other, pointing at the same time to the danger into which a sound boiler may be thrown by an explosion.

Fig. 2.



(The edges of the plates are cut to an angle of 65° by means of inclined shears.)

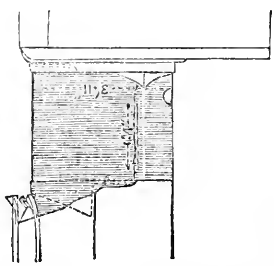
Upon the same principle it is probable that the modern guns, built up from strained rings, will be easily put *hors de combat* by shot. The probability is that a number of simultaneous strains in different directions diminish the elasticity of the material that would allow it to yield in any given direction. However this may be, it will be seen that it is only the pressure on the ends of the boiler acting parallel to the axis and tending to tear the cylinder through transversely, which bears fairly on the rivetted joint, or rather on that metal between the rivets which is left after punching. Unless the cylinder be perfectly correct inside, the circumferential strain resolves itself into cross bending, shifting the dangerous strain from the iron left after punching to the metal at the overlap. With respect to the stress tending to bulge the cylinder in the centre, it is clear that if we suppose a strip cut out from the entire length of the boiler, each portion of the length of this strip could be regarded as a beam under a uniformly distributed load.

As, however, with the lap-joint there is a double thickness of metal transversely, that joint is the strongest and stiffest portion to resist the stresses tending to bulge out the cylinder in the middle, and also to tear it into two halves. This affords some justification for the belief of old boiler makers, before rivetted joints were tried under a direct tensional load, that the joints are the strongest part of the boiler. And, indeed, this is what we find in practice. The thinest portion of the longitudinal furrows is generally exactly in the middle of the plate, and this is caused by the longitudinal stress, which is acting at right angles to the transverse cross bending stress. A strip cut from joint to joint is, in one respect, in the condition of a beam supported at both ends, uniformly loaded throughout its length, and, according to known principles, therefore giving way in the middle. (See Fig. 3.)

The middle ring of the boiler which burst on the Metropolitan Railway last year, and the fragments of which were examined by the writer, also first given way at a furrow. Captain Tyler reports that at from $16\frac{3}{4}$ to 19 inches from the transverse joint, or just about the middle of the plate, there was "very little metal left holding," while it gradually got to its original thickness of $\frac{3}{8}$, as the groove receded from the centre of the plate and towards the transverse joints at each side.

It is impossible to deny the existence of an infinite number of stresses acting on the sides of a vessel undergoing fluid pressure, producing what, for want of a better term, might be called a "bulging strain." Instances of this action may be noticed in the sketch of the leaden pipes given by Mr. Fairbairn,* which were bulged out in the middle by internal pressure, as also in the fire-box sides† influenced by the same means, and in the centre of the surface. Unaccountably enough, the effect of such a strain on the ultimate resistance, and, above all, the elasticity of materials, has been entirely neglected by investigators, and there are no published data on the matter. The effect of the internal pressure is evidently resisted by a double thickness of plate at the joints, so that the load on the middle of a single ring may be considered as determining the weakest part of the boiler. One of the rings of the Great Northern boiler which exploded on the Metropolitan Railway last May had a length transversely of about (say) 36 inches from lap to lap, with an inside diameter of 45 inches. If we now suppose a strip one inch broad cut from the 36-inch long plate, parallel to the longitudinal axis of the boiler, this strip is, supposing there be a pressure of 100 lbs. to the square inch, uniformly loaded with 3600 lbs., equal to a transverse load of 1800 lbs. at the

FIG. 3.



(From Captain Tyler's report, dated 30th June, 1864, on the boiler explosion at the Overton station of the London & North Western Railway. The plate torn off is shaded, the course of fracture on the other side of the boiler is dotted, while the furrow is shown by the thick horizontal line.)

* "Philosophical Transactions, 1858," page 402.

† "Useful Information for Engineers, 1856." Appendix, xviii.

centre. Supposing the plate to form a true circle, a hoop one inch wide of the $\frac{3}{8}$ plate would be subjected, circumferentially, to a tensile load of 6000 lbs. per square inch, while (leaving out the diminution of the area at the ends through the flue tubes) each portion of the circle about 1 inch broad and $\frac{3}{8}$-inch thick, is subjected to a load of about 1125 lbs. acting parallel to the axis of the boiler.

To construct a general rule or formula that would take into account the distorting effects of the lap or of the welt of butt-joints would be impracticable; but it is clear that the usual mode of calculating the strength of a cylindrical boiler from the tensile strength of joints tested by weights, or hydraulic pressure, directly applied, is far from being correct. It is only tolerably correct with scarf welded joints, or with butt-joints with outside welts. Even here, the hoop tension of the true cylinder is resolved into a cross bending strain, if the cylinder does not form a correct circle internally. The usual formula would be practically correct, if the boiler were prevented from altering its shape during the impulses sometimes given by the steam, and the quieter buckling action caused by the alternate increase and fall of the pressure. In fact, a boiler, like a girder, does not merely demand a high ultimate strength, but also a stiffness which is the protection against alternative strains—against buckling or collapse.

Disregarding the effects of the thickness of the material, a perfect cylinder should theoretically afford the same ultimate resistance, whether exposed to external or internal pressure. Its resistance to collapse should indeed be greater, as most materials give more resistance to compression than to tension. This is not the case, as the distortion of form progressively weakens an internal flue, by increasing the load on its surface, while the contrary is rather the case with the boiler exposed to internal tension. Before Mr. Fairbairn showed the inherent weakness of flue tubes, their frequent explosions through collapse were ascribed to spheroidal ebullition and other similar causes. They are now, according to the engineer of the Manchester Boiler Association, stronger than the shells, by means of the T-iron and angle iron bands now generally used, and also by the excellent seams introduced by Mr. Adamson so long ago as 1852.* While T-iron and other bands could be used for the barrels of boilers not exposed to the fire, (as is recommended in France† and by the Board of Trade Inspector of Railways,) Adamson's seams reversed would probably form excellent transverse joints for a shell fired from the outside, and, with a boiler like this, thin and narrow plates could be used, affording a stronger and tighter lap-joint. With a construction of this kind little or no deflection or bulging could occur, and the sectional area of the plate and the rings would really give the strength of the boiler.

* Specification No. 14,259.

† Bulletin de la Société Industrielle de Mulhouse, 1861, page 532.

(To be continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

The Problem of the Gyroscope. By JAMES CLARK.

NEW YORK, June 24, 1865.

Dear Sir: I enclose you herewith a solution of the problem of the gyroscope, which had occurred to myself before seeing any other, and which, if not novel in principle, I think will at least be found new in method. Further, I think it explains many things left obscure in most of the solutions hitherto published.

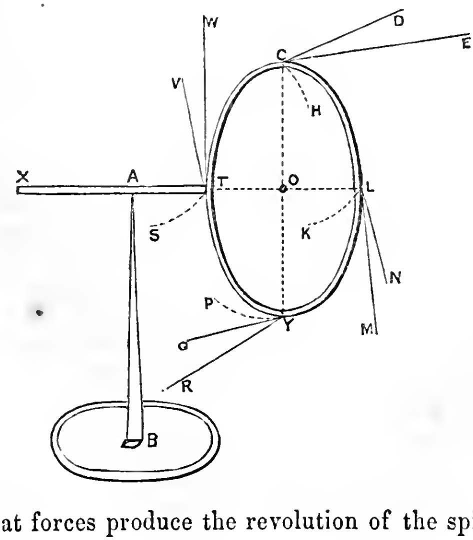
I am induced to offer it for publication at present, among other reasons, because the solution published in the New American Cyclopedia, towards the end of the article "Gyroscope," is palpably erroneous. The writer, in the first place, not recognizing the force generated by the rotation of the spindle about the pivot, as having anything to do with the supporting of the wheel; and, in the next place, he accounts for the rotation of the spindle by the fact that the revolution of the wheel is, on one side, *against*, and on the other, in conjunction with, gravity, both of which conclusions are demonstrably wrong.

Very respectfully,

JAMES CLARK.

The gyroscope, in its simplest form, consists of a wheel or disc revolving on an axle, which rests on an upright pivot, as represented in the annexed figure. When the wheel is set in rapid revolution, and the end of the axle or spindle opposite that on which the wheel revolves is placed on the pivot, the wheel and the end of the axle on which it revolves, will remain supported as indicated in the diagram, and the axle or spindle will rotate about the pivot in a direction opposite to that in which the *top* of the wheel revolves on the axle.

An analysis of the forces producing these phenomena, is what is required by the problem of the gyroscope.



First. What forces produce the revolution of the spindle A O about the pivot A?

If we begin with the particle of matter situated at the point C in the circumference of the wheel, we will find it acted upon by two forces —the centrifugal, which tends to impel it in the direction of the tangent C D, and that of gravity, modified by the suspension of the axle on the pivot A B, the tendency of which is to cause the particle to describe the arc C H. The resultant of these forces, by a well known mechanical law, gives to the particle at C an impulsion in the direction of the line C E, diagonal to the tangent C D and the arc C H*; and the like may be predicated of every particle of the wheel *above* the horizontal diameter T L. The resulting tendency of the forces acting on all these particles, then, is to change the plane of revolution of the wheel to one diagonal to the two planes perpendicular to the horizon, which respectively contain the tangent C D and the arc C H. Now, the wheel can only assume this new plane of revolution, or one parallel to it, by moving *backward* in a direction opposite to that in which the *top* of the wheel revolves, which it is free to do by the rotation of the spindle about the pivot A. If we consider the particle at Y, (and the like is true of every particle situated *below* the diameter T L,) we find it likewise acted upon by the centrifugal force in the direction of the tangent Y R, and by gravity, (modified as explained above,) in the direction of the arc Y P. The result is a tendency to produce motion in the direction of Y Q, the diagonal between the direction of these forces, and, consequently, (Y Q being parallel to C E,) to change the wheel's plane of revolution into the same plane into which it is impelled by the forces acting on the particles situated *above* the horizontal diameter.

We have now accounted for the rotation of the spindle about the pivot A B.

Secondly. It remains to account for the paradox of the wheel's continuing supported in the air.

If we take the particle situated at T, (and the like is true of every particle situated on the same side of the perpendicular diameter C Y,) we discover it is acted upon by the centrifugal force, in the direction of the tangent T W, and by the force communicated by the rotation of the spindle about the pivot A B, in the direction of the arc T S. The result is a tendency to impel the particle at T in a line T V, diagonal to the tangent and the arc, and the wheel into a plane of revolution diagonal to the horizontal plane which contains the arc T S, and the plane perpendicular to the horizon and to the axle A O, which contains the tangent T W.† But the wheel can only assume this new plane of revolution, or one parallel to it, by the *elevation of the extremity* O *of the spindle on which it revolves.* In like manner, the particle situated at L, (and the like is true of all particles on the same side of C Y,) is

* It is, perhaps, not strictly correct to speak of a line as diagonal to a right line and a curve. It would be more exact to say, that the resulting impulsion given to the particle at C, is in the direction of the diagonal between the tangent C D and a tangent to the arc C H at C.

† The spindle is here assumed to be placed on the pivot at right angles with it, which is not necessarily the case; and the angle at which it is placed may subsequently vary, accordingly as the elevating tendency is greater or less than the force of gravity.

acted upon by forces tending severally to impel it in the direction of the tangent L N, and of the arc L K. The evident result is a tendency to impel it in the direction L M, and to produce the *same change* in the plane of revolution of the wheel, that we have already shown to be the effect of the forces acting on the particles on the other side of C Y; and it is this constant *effort* to change the plane of revolution into one which, or a plane parallel to which, the wheel can only assume by elevating the extremity of the axle, which prevents it from falling.*

The whole may be thus summed up.

The rotation of the spindle on the pivot, is the resultant of the action of gravity and the centrifugal force generated by the revolution of the wheel on the axle; while the wheel is prevented from falling by the combined action of the same centrifugal force and the rotation of the axle on the pivot.

COROLLARY 1. If the extremity of the spindle opposite the wheel, be prolonged beyond the pivot in the direction A X, and a weight be placed at X somewhat more than sufficient to balance the wheel, the spindle, instead of rotating about the pivot in a direction *opposite* to that in which the top of the wheel revolves, will rotate in the *same* direction.

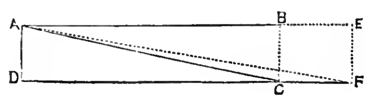
COR. 2. If the weight exactly balance the wheel, the spindle will cease to rotate about the pivot.

COR. 3. If the weight be removed, and the rotation of the spindle be stopped by the interposition of any obstacle or opposing force, the wheel will fall.

COR. 4. If the weight be suffered to remain, and be more than sufficient to balance the wheel, and the rotation of the spindle be stopped, the wheel will tilt upward.

OBSERVATION. Another fact remains to be considered, viz: the resistance offered by a body in motion to any force tending to divert or deflect it from the direction in which it is moving.

Suppose a body placed at A, to be impelled in the direction A B, by a force sufficient to carry it to B in a given time. Now, if the same body be simultaneously acted upon by another force in the direction A D, sufficient to carry it to D in the same time, by a familiar law already alluded to, the body will move in the diagonal A C, and will reach C in the same time in which the forces acting singly would carry it to B or D.



The point to which attention is invited is this, that while the second force, if acting alone, would impel the body in the direction A D, when the same force acts in the same direction on the body simultaneously impelled toward B, with a force proportioned to that acting in the direction of D, as A B to A D, the path A C described by the body, *more nearly coincides with the direction of the*

* If the spindle be placed on the pivot so as to form either an acute or obtuse angle with it, it is evident that the centrifugal force generated by the rotation of the spindle about the pivot, will *tend* to bring the spindle at right angles with the pivot; in the former case, acting in aid of the elevating force, in the latter, in opposition to it.

stronger force; and if we increase that force, so that it shall bear to the other the ratio of A E to A D, A F, the path of the body will be still more nearly coincident with A E. Whence it follows that *a moving body resists diversion from the direction in which it is moving, and this resistance is in the compound ratio of its quantity of matter and velocity.*

If we apply this principle to a wheel or other body revolving on an axis, and, leaving out of view the thickness of the revolving body, consider that the centrifugal force tends to impel every particle in the direction of a tangent to the periphery of the circle in which it revolves, and that all these tangents lie in the *same plane*, (perpendicular to the axis of revolution,) we can readily perceive that the revolving body will resist any change of its plane of revolution, or, (which is the same thing,) of the direction of its axis, with a power proportioned to the momentum generated by its revolution. If we take the thickness of the wheel into account, we find the particles revolving in a series of *parallel planes*, with a like tendency to resist change.

It is this principle which gives to rifled fire-arms their chief advantage in point of accuracy. If we regard the projectile discharged from a piece of this description as moving in a right line, (which is virtually true of short distances,) its plane of revolution is at right angles to its line of progression; in other words, the axis of revolution coincides with the line of projection. It is evident that the tendency of revolving bodies to preserve the identity or parallelism of their planes of revolution, and, consequently, to maintain the direction of their axes, strongly operates to continue the ball in the line of the original impulsion.

If we apply this law to the gyroscope, it will readily be observed in what manner it co-operates in preventing the wheel from falling. For, one end of the spindle being sustained by the upright pivot, the wheel can only fall by describing the arc of a circle, the centre of which is the point of the pivot and the radius, the spindle. But to fall in this manner, requires a constant change of the wheel's plane of revolution, the tendency to resist which has already been explained.

For the Journal of the Franklin Institute.

A New Process for Extracting Gold from Auriferous Ores, and particularly applicable with great advantage to Pyrites and other Ores containing Gold in small quantities. By H. JACKSON and W. A. OTT.

Amongst the different improvements lately adopted for the extraction of gold from auriferous ores, the process of Professor Plattner, of Freiberg, (Saxony,) occupies the first range, as well for its ingenuity as for the advantages to be derived from the same. In this country, on the contrary, the quicksilver or amalgamation process is almost universally practised, and each improvement which possibly could be made has been adopted, so that it may be said the process of

amalgamation has arrived at a point where still better results cannot be expected. Though well known and extensively practised for many years, nevertheless it is not free from considerable defects, which, in relation to economy, never will be obviated. This is a fact generally acknowledged, and the process of amalgamation would have been abandoned if there should exist a more practical and improved mode of extracting gold.

The said process of amalgamation cannot be applied advantageously to the treatment of poor ores on account of the great division or distribution of the gold, thus causing an imperfect contact with the quicksilver, and consequently an imperfect amalgamation. Numerous trials and experiments have proved the impossibility of avoiding these defects, even if the operations of the amalgamation are conducted with the most scrupulous care.

For these reasons Professor Plattner, one of our most ingenious metallurgists, suggested the extraction of gold by means of chlorine, which has been introduced at Reichenstein, (Prussian Silesia,) where immense quantities of certain auriferous residues from the preparation of arsenic had been accumulated since several centuries. These residues being extremely poor of gold, and not fit for being treated by any other known means, nevertheless afforded a considerable profit by the treatment with chlorine.

The same satisfactory results have been obtained at Schemnitz and Schmœllnitz in Hungaria, and other localities, where large hills of residue, formerly considered worthless and thrown aside, are worked over again and every trace of gold extracted.

Plattner, perfectly posted up in theory and practice of all metallurgical operations, soon came to the conclusion that his process might undergo an alteration or improvement in relation to the treatment of natural ores, and especially such ores as contain the gold in a mineralized condition, but, by his premature death, he was prevented from finding out such improvements.

Since Plattner's death nobody on the other side of the Atlantic has taken particular pains to apply his process to the treatment of natural ores, for the reason that gold-bearing ores are comparatively rare in Europe.

In order to explain the defects of this process, we deem it necessary to go into some details, and to report afterwards on the method of extracting gold, for which letters patent of the United States have been granted to us in the month of April, 1865.

Previous to the treatment of chlorine, the ores must be pulverized as finely as those which shall be submitted to the process of amalgamation. Ores containing sulphur must be roasted until all other metals contained therein have been transferred to the highest point of oxidation, being in this condition but very little attacked from chlorine, while gold almost alone will be dissolved. The ore thus first prepared is carried into earthen jars or wooden barrels lined inside with lead, and chlorine gas is passed through the ore so as to impregnate it thoroughly. After this operation, lukewarm water is to be poured over

the ore; the resulting filtered lye of gold is precipitated by sulpho-hydrogen, and the precipitate thus obtained from the sulpho-combination of gold and other metals is dissolved in aqua regis, and by an addition of sulphate of iron the metallic gold will be obtained in a finely divided condition, free from silver or copper and fit for direct melting.

This treatment answers perfectly well for quartz containing gold in very small particles, and for ores containing very few sulpho-metals, and requiring no completely and costly desulphurization, and it answers also for residues, though the apparatus prescribed by the inventor does not allow operations but on a small scale. For treating ores rich in sulpho-metals, like our ores from Colorado, the application of the said process meets with two serious inconveniences, viz:

1. An excess of chlorine is necessary, and
2. The remaining ore is very seldom completely exhausted and contains still some gold.

If we examine specially these two faults, we find that the cheapest mode of chlorinizing would be, if just as much of the chlorine gas could be used as might be necessary for the dissolution of the quantities of gold contained in a certain ore. But that, perhaps, never will be the case, and we always shall need a large portion of chlorine; whereas the finely divided ore, and particularly the oxides therein contained, will absorb the gas without binding it chemically.

According to Plattner's plan of treating the ore, a considerable quantity of gas must be lost, and consequently the expenses will be increased the more as the ability of the ore for absorbing the gas may be very strong, and as the prices of the acids and other materials necessary for the preparation of the gas may range high. If this inconvenience cannot be set aside completely, it is, however, possible to do so partially in a manner we cannot describe here more particularly.

It may be enough to mention that, by applying a peculiar desulphurizing process, we save near one-half of the amount of gas from that required at the works of Reichenstein.

This is the first advantage afforded by our process.

In Plattner's process another inconvenience is to be found in the following:

In consequence of an imperfect roasting and of the existence of basic salts and sulpho-metals, combinations of chlorine and sulphur may be created, which, while producing a secondary decomposition, will exert an influence on the chloride of gold already formed, and will separate a quantity of the metallic gold proportional to the quantity of the sulphur, thus being lost for the process.

A complete roasting, going as far as to remove every trace of sulphur, no doubt would be the best means of obviating this inconvenience, but whoever knows the difficulties occurring in the practice, particularly when operating on copper pyrites, will give up the execution of such a plan.

In our process we obviate the precipitation of the gold in a different

manner, that is, by substituting hypochlorous acid (a gaseous body consisting of 1 eq. chlorine and 1 eq. oxygen) for the chlorine gas, and by submitting the ore to the effects of this gas. The hypochlorous acid gas, when brought in contact with the combinations of sulphur remaining in the ore experiences a decomposition, the oxygen uniting with the sulphur and transferring it into the highest degree of oxidation while the chlorine combines with the gold. By the application of the said gas to the process of extracting gold, we are enabled to secure two important advantages, namely:

1. We obviate entirely the formation of injurious agents by means of the oxidizing effect of the oxygen, and
2. The chlorine is acting while in *statu nascent*. In this state the chlorine has reached the highest degree of chemical affinity, thus making our process (besides its ability of promoting the close of the operation) applicable as well to ores containing gold in finely distributed particles, as to such ores which may contain gold in coarser particles.

Having explained the two chief points which distinguish our process from Plattner's mode, we deem it necessary to say a few words in regard to the question whether it is applicable in a large scale.

Our process requires, like all others, a complete pulverization, and next a good roasting, if the ore should contain sulphur. In case the ores should contain copper, it would be advisable to submit them to a roasting, and to extract the formed copper salt by water, and to precipitate the copper by proper means. In both cases the ore is ready for being treated by the hypochlorous acid.

The question now arises whether this gas can be produced at a sufficiently cheap rate. In view of the enormous quantities of it produced for the preparation of bleaching salts and especially of chloride of lime, we may confidently give an affirmative answer. We do not need for our purposes any other apparatus or localities than those required for the manufacture of the before-mentioned articles, except a leaden retort, which should be placed between the generator of the chlorine and the buildings for the storage of the ore. This retort is filled with a solution of sulphate of soda or glaubersalts, and we thus obtain the hypochlorous acid in a free condition.

The generator of the chlorine in proportion to the impregnating chamber requires smaller dimensions than those necessary for the manufacture of chloride of lime. The impregnating chamber is constructed from silicious sandstone or from bricks in a longitudinal form, and represents a room rather more high than wide. It must be coated inside with asphaltum, and boards 8 to 10 feet long and 2 feet wide should be fastened horizontally along the large sides, one above the other, allowing spaces of about 4 inches between them. These boards are designated for receiving the ore. In the middle of the building a small gangway is to be left; two windows allow to watch the operation, and one door affords admittance to the chamber. A green color will be observed at the windows when the impregnation is completed, and the door thus far tightly closed, then may be opened for the exit of the gas and for the removal of the ore.

The next operation, *i.e.*, the extraction of the ore, is performed either by centrifugal power or by a hydraulic press and water. In this manner we obtain a very concentrated lye from which we precipitate the gold either directly by sulphate of iron, or by a treatment with sulphohydrogen and subsequently by sulphate of iron.

Both operations are very simple and do not require any particular or costly apparatus.

Compared with the process of amalgamation, and in consideration of the expenses for putting up such an establishment being equal, our process, besides the before-mentioned advantages, affords still others, viz:

1. The value of the materials entirely disappearing out of the operations is considerably less, whereas we are working with materials far cheaper than quicksilver.
2. We save great expense of fuel, indispensable for the distillation of the quicksilver.
3. We need no refining, pure gold being precipitated from the solution of the chloride of gold.
4. Our process is not injurious at all to the health of the operators.

Atmospheric Pressure as a Source of Mechanical Power.

(Continued from page 209.)

Fully to appreciate the value of atmospheric pressure as a source of mechanical power, it should be considered not only in contrast but in connexion with the steam engine, and to that the present section is given.

There are some points about steam not generally known, or if known seldom thought of.

1. Quantity for quantity, low steam costs the same in fuel as high steam; or, as laid down in the books, "The same quantity of heat is sufficient to convert the same weight of water into steam whatever be the pressure under which the water is boiled, or whatever the pressure and density of the steam produced."

2. There is the same force in the lowest as in the highest steam; the condensation of the former under a piston exciting an amount of atmospheric pressure equal to the expansive force of the latter against it. In other words, "the same quantity of water converted into steam produces the same mechanical effect whatever be the pressure or the density of the steam."

3. There is no augmenting the natural power of steam. As well might we think of increasing the weight of the atmosphere. To obtain more power from it we call into action more of it, and that is the only means by which additional power is to be had from it. Its force rises and falls with its quantity. A quart compressed into the space of a pint exerts an intenser force than when in the quart, but it is on a smaller surface. The pint can do no more work than the quart. One law governs all forces. A pound weight on a lever

balances several pounds by moving it further from the fulcrum, still it is only a pound with the force of one. So a pound of steam can no more do the work of two pounds than a pound of metal—no more than one horse can do the work of two horses. The pressure within a boiler increases with increased accumulation of steam.

4. The terms *condense*, *condensation*, &c., are apt to convey, to some minds, the same idea as when applied to solid bodies, as rendering metals more dense by hammering or when passed through rollers; whereas, here they indicate the production of a void by the vapor shrinking into a minute part of the space it filled—as gallons of steam into thimblefuls of water.

The foregoing borne in mind, all that follows may be understood by others than practical men. They will perceive two forces in steam, of which one begins to act as the other ends; and that its power continues from its birth in the boiler to its last gasp in the condenser. Moreover, that heat is the element of force and steam the agent or medium by which it acts, and consequently fuel only is consumed and has to be renewed. A small quantity of water might furnish an indefinite amount of steam. Being revived in the boiler as fast as it expired in the condenser it might circulate through them forever.

The great lever of modern civilization and essential to its progress, steam has immeasurably more work to do than it has done. It has to be cheapened, and to effect that more work has to be got out of it. Rich in that which is the source of all wealth, its economical applications are among the most important desiderata; for the fact is incontrovertible, though almost incredible, that not over *one-third* of its power has yet been utilized, consequently two-thirds of the fuel expended upon it are lost.

Like the permanent gases, steam is a fluid *spring*, differing from solid ones in the form of its action. Instead of bending to and fro, it swells and shrinks. In the range of its movements it surpasses those made of metal. They are derived from ores; it comes from water, of which one volume swells into seventeen hundred and shrinks back into one. No clearer idea of its capacity and functions can be had than by considering it as an elastic instrument of motion. Heat winds it up and cold unwinds it. Like other springs it has two movements, equal in power, but in opposite directions, and both must be used. To neglect either is to lose half of the power. For high-pressure motors the spring is wound up and allowed to run down to waste, while for an atmospheric one the shrinking movement is used and the swelling one passed by as if of no account.

There can therefore be no doubt, however valuable atmospheric engines may be for particular purposes, that the truest application of steam, as an agent of force, is to associate high pressure engines, the greatest wasters of it, with atmospheric ones which blow off none. All the heat will then be utilized, and when that is done practice will conform to theory and be perfect.

As the two movements or forces bear the same relation to each other as action and reaction, if the amount of one be ascertained it

must be the same as that of the other; hence if the expansive power is not easily traced to the vanishing point, we know exactly what it is by the vacuum condensation produces. They have given rise to two classes of engines, high-pressure or non-condensers and condensers.

Non-condensing engines, the most numerous and popular, are operated solely by the swelling or expansive force, and consequently cannot turn to account more than half the power in it. They do not, however, do that nor anything like it. There is a mechanical difficulty in the way, the consequence of which is that they utilize only about half the expansive force, and therefore only *one-fourth* of the power. A cubic inch of water evaporated under a piston raises a ton a foot high; there the force and resistance are balanced, and there the piston of the engine stops; the force remaining in the fluid being dispersed with it for lack of means to use it. A steel spring half uncoiled can be removed and its unexpended force employed, but engineers do not yet know how to do that with steam that has spent part of its force in the cylinder of an engine.

To lessen the loss, most engines "work steam expansively." That is, the cylinder is only partially charged, by cutting off the communication with the boiler at certain stages of the stroke, the portion admitted being left to dilate and follow up the piston to the end of the stroke. The alleged gain from this arrangement is considerable. It would be complete instead of partial if expansile and contractile pistons, working in conical instead of cylindrical chambers, could be used, as they would present enlarging areas to decreasing pressures, and receive and impart a full and equable effect from a varying force. The device, however, is apparently not within the range of our present mechanical appliances.

The amounts of expansive force escaping in the volumes of waste steam from high pressure engines are obvious. Whether the European estimate of this loss be exaggerated or not, the fluid goes through such as make 50 strokes and upwards per minute, with great rapidity. The piston acts but as a momentary check on its passage from the boiler to the waste-pipe. The temperature and amount can be but little reduced.

Of the vast and increasing numbers of high-pressure engines there is perhaps not one proprietor in a hundred prepared to believe that in his waste pipe he throws away as much power as he realizes; and if next told that the amount is nearer twice as much, derision would probably succeed to incredulity. The clouds of steam ascending daily from engines located on the East and North Rivers, afford such proofs of economy, as dumping off the docks half the quantity of coal consumed in heating their boilers would be.

Condensing Engines.—These call into action both forces, and, strange to say, they yield little more than half of one of them; and this, too, in the face of the fact that, while there is a difficulty in the way of obtaining the entire expansive force, there is none whatever in realizing by condensation the whole of the contracting force. Lard-

ner, in his work on the Steam Engine, thus speaks of both classes:—

"In engines which do not condense the steam, and which, therefore, work with steam of high pressure, some of the sources of waste are absent, but others are of increased amount. If we suppose the total effective force of the water evaporated per hour in the boiler to be expressed by 1000, it is calculated that the waste in a high-pressure engine will be expressed by the number 392; or, in other words, taking the whole undiminished force obtained by evaporation as expressed by 10, very nearly four of these parts will be consumed in moving the engine, and the other six only will be available.

"In a single acting condensing engine, taking, as before, 1000 to express the total mechanical power of the water evaporated in the boiler, 402 will express the part of this consumed in moving the engine, and 598 therefore will express the portion of the power available; or taking round numbers, we shall have the same result as in the non-condensing engine, viz: the whole force of the water evaporated being expressed by 10, 4 will express the waste and 6 the available part.

"In a double acting condensing engine, the available part of the power bears a somewhat greater proportion to the whole. Taking, as before, 1000 to express the whole force of the water evaporated, 368 will express the proportion of the force expended on the engine, and 632 the proportion which is available for the work.

"In general, then, taking round numbers, we may consider that the mechanical force of four-tenths of the water evaporated in the boiler is intercepted by the engine. In this calculation, however, the resistance produced in the condensing engine by the uncondensed steam is not taken in the account: the amount of this force will depend on the temperature at which the water is maintained in the condenser. If this water be kept at the temperature of 120°, the vapor arising from it will have a pressure expressed by three inches seven-tenths of mercury; if we suppose the pressure of steam in the boiler to be measured by 37 inches of mercury then the resistance from the uncondensed steam will amount to one-tenth of the whole power of the boiler; this added to the four-tenths already accounted for, would show a waste amounting to *half the whole power* of the boiler, and consequently only half the water evaporated would be available as a moving power.

"If the temperature of the condenser be kept down to 100° then the pressure of the uncondensed steam will be expressed by two inches of mercury, and the loss of power consequent upon it would amount to a proportionately less fraction of the whole." Again, "If the direct force of high pressure steam be combined with the indirect force produced by its condensation, the total mechanical effect will be precisely equal to the mechanical effect of the condensation of atmospheric steam."

That is, six-tenths is the sole practical value of *each* of the forces, *and of both combined!* Less than one-third of both. Whereas, if the contracting force did not disappear, somehow or other, in the engine,

the result should and would be over two-thirds instead of less than one.

Hence the question naturally arises—If condensing engines produce no more power than non-condensing ones, why employ them at an increased expense of machinery and of power intercepted by it; and if the expanding and contracting forces produce, when combined, only the effect of one, why use them in combination? Is there not something here that wants explaining? Force within an engine that does not come out must be absorbed by the mechanism or neutralized by its arrangement. We know that separately the two forces act perfectly, and hence when their united effect is not double that of one of them, it can only be ascribed to their combination.

There is no difficulty in collecting separate forces into one motive power, like affluents of a river into a single channel, when they coincide in their bearing or course, but it is otherwise when they move in opposite directions. To make such coalesce they must be separately evolved. How can two conflicting ones as heat and cold, shrinking and swelling, be combined without their joint effect being less than their separate action? Can anything be more certain, than that steam discharged from a non-condensing engine will, as readily as direct from a boiler, produce as much more power if passed into an atmospheric cylinder? Compact machinery is a favorite doctrine, but it may be carried too far. The condensing steam engine is an example.

Heat not used up is wasted, but theory tells us it ought to be wholly utilized. How is that to be done? In the way that nature does it—by first using the expansive force and then deriving an *equal* amount from contraction.

Now, while the indirect force of steam in shrinking into a liquid equals its direct pressure against a piston, how is it that condensing engines are not more productive? Because they condense *compressed steam*, and *limit the effect of the vacuum to the area of the piston.* Perhaps it will be said that when an engine is worked with 30 or 60 pound steam it does not follow that such is its tension on leaving the cylinder, since in most cases it is reduced by expansion through the operation of the cut-off. Granted; yet it cannot be reduced below the resistance, so that at whatever tension it is above that of atmospheric vapor, just so much is wasted, so much power thrown away. But suppose it dilated till barely sufficient to balance the atmosphere; what then? would not the effect be the same as long as the vacuum is confined to the piston? If several cubic feet of common steam be compressed into a cubic foot, would not *each*, on being released, swell into its previous volume and be as valuable for producing a vacuum in a working cylinder of the capacity of a cubic foot as the condensation of the whole of them in it? That is what our engines should be made to do; instead of which they extinguish the life in several volumes for the sake of one, and consequently get no more than the effect of one out of them. This is that which enfeebles them, nor can it be removed except by using steam too weak to move the piston at all. It is ex-

pensive as well as inherent; for in condensing more than is necessary there is a loss of power, and a loss that increases with the excess. It would be better to blow off the surplus, if that could be done, than to waste power over it. Such is the result of a misalliance, or vicious combination, of expansion and collapsion in *the same cylinder.*

Is it asked how the evil is to be avoided? By cutting off the communication between the condenser and working cylinder, and discharging the steam from the latter into an atmospheric one, its capacity being determined by the intended pressure of the steam, or the number of times it will admit the working cylinderful of high or compressed steam to expand into low, or uncompressed. Thus, an engine working with 60 ℔s on the inch, one cylinderful would expand into four at common or atmospheric pressure, at 90 ℔s into six, at 120 ℔s into eight, at 150 ℔s into ten. Whatever the number, it will be found that the force evolved by condensation is equal to that of expansion. For example, a cylinder working with steam of 60 lbs. and the area of the piston 50 square inches, the expansive pressure will be $60 \times 50 = 3000$ lbs. On the other hand the fluid would fill four cylinders of the same dimensions, or one with a piston of four times the area; hence $50 \times 4 \times 15 = 3000$ lbs. of atmospheric pressure. By the present system the vacuum, instead of yielding 3000 lbs., would probably not yield 300. According to the authority quoted —which has not been questioned—it would yield little or none.

Whatever other advantages may be claimed for the condenser of Watt, as respects economy of power it was a decided failure—the continued use of which can only be accounted for on the ground of passive and unreflecting obedience to his rules. He appears to have been embarrassed by the claims of the two opposite forces, and made a compromise between them instead of giving each its full scope by itself. The air-pump crippled both. It took steam to work it, and produced no better vacuum than Newcomen had without it. It checked the employment of high and even steam of medium pressure. But for it, he would have made more manifest an alleged preference of the expansive over the contracting power. A philosphical friend gave currency to the statement, that his condenser was originally suggested as an economical appendage to Newcomen's engine. This he contradicted, saying: "From the first I intended to operate with steam instead of the atmosphere, and my apparatus was so constructed." (Stuart's Anecdotes of Steam engines.)

Notwithstanding this, "the three great steps in the brilliant career which has immortalized his name," had every one of them reference to atmospheric pressure: 1. Condensing in a separate chamber was to avoid the cooling of the cylinder by the jet playing in it. 2. Maintaining the vacuum by the air-pump and its accompanying hot and cold water pumps. 3. Closing the open end of the cylinder to avoid the cooling effects of the air on pushing down the piston, and requiring, as in the case of the jet, more steam on the ascent of the piston to reheat it.

The leading inquiry in discussing the value of motive forces is not what power *is* got out of one, but how much *can* be got out of it. We

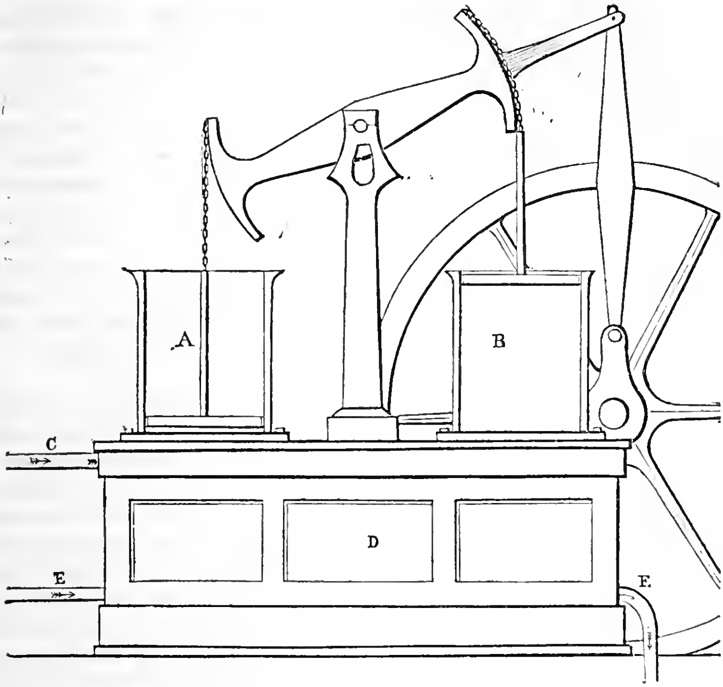
know exactly how much there is in steam, high or low. If Watt had used the former, and passed the steam from his cylinders into atmospheric ones he would have left little for his successors to do.

Of fourteen marine engines built by one firm in this city, the average cylinder is 45 inches diameter, with $8\frac{1}{2}$ feet stroke; the air-pump 30 inches and $3\frac{1}{2}$ feet stroke. All, except three, are calculated to work with steam up to 30 lbs. on the inch; hence every cylinderful at that tension contains three of common or uncompressed steam, and, when condensed as one, two-thirds of the power which might be drawn from it are lost. The cylinder holds 93 cubic feet, the condensation of which ought to contribute an amount of force equal to 93 tons raised one foot. We know it does not and cannot yield half of it; yet that amount ought to be doubled if the vacuum were produced in separate cylinders.

When the subject is duly considered, the inducements to adapt condensers to atmospheric cylinders, can hardly be resisted, as generally double the power will be obtained with no extra working expense but that of ice or water for condensation, and not even that for adding to the power of *marine engines*, as they have it without pumps to raise it. As the power increases with the pressure of the steam, such engines instead of 30 lbs. on the inch may be safely reduced in their dimensions and worked at double or treble that amount. None can more readily and beneficially realize the change. Their steam cylinders may be converted into atmospheric ones, and replaced with others one-third or one-fourth their size. Economy as respects space is not more obvious than in fuel and power. To increase the power of a steamer's engine at present, she must take in a larger cargo of coal; on the plan here presented she need not take in an additional bushel.

Invaluable beyond expression as steam power is, and is to be, it is strange that atmospheric pressure has not been more cultivated. It is uniform, while that of steam is variable and always less in the cylinder than in the boiler. The full effect of the vacuum is obtained on the easiest terms, whereas from the direct pressure of the steam there is a heavy discount. Make all engines on the proposed plan, and the steam power of the world may be doubled, if not more than doubled wherever water is cheaper than coal; and, as with marine engines, requires neither cartage nor stowage.

To engineers it would be superfluous to add anything more; but there are those who do not perceive how fresh force is to be got out of waste steam without fresh fuel, nor how it is to be used. They want something more to make the matter clear to them, and for that purpose the annexed figure is introduced. They understand how one force is the production of heat, and it will explain how the other is evolved by cold, or the abstraction of heat. The steam cylinder is left out, as its action requires no explanation. Its waste pipe is all that is wanted to supply the steam that is to be converted into power. A portion of it is represented.



A and B are sections of two atmospheric cylinders open at top, each being two or three times the capacity of the steam cylinder, according to the pressure of the steam used. C, the waste steam-pipe; D, the condenser; E, the cold water pipe; F discharges the heated water. The positions of the pistons indicate that the steam piston has just descended in its cylinder and discharged its contents into B. On being condensed, the piston of B is pressed down by the atmosphere and that of A at the same time raised to receive the steam from the upward stroke of the steam piston, which, on being in its turn condensed, excites the pressure of the atmosphere to press down the piston of A and raise that of B. The fly-wheel, as usual, carries the crank over the dead points. The valves to admit the steam alternately into A and B, and those that turn on and off the condensing water, are too well known to require being figured.

Of course it makes no difference whether the steam cylinder be horizontal or vertical, fixed or oscillating.

As the atmospheric pressure on the pistons of A and B is limited to their downward stroke, their rods are here represented as connected to the vibrating beam by chains. But as the force of the steam on first entering will suffice to raise them through a considerable part of the stroke, which is so much power gained, the connexion should be made in the usual manner.

In this way the two forces may operate two distinct engines, one

animated by fire, and power in the other evolved by water. Taken together they constitute the most effective device for eliciting and economizing the motive fluid, and this they do by the natural process of giving each its full play, unembarassed by the other.

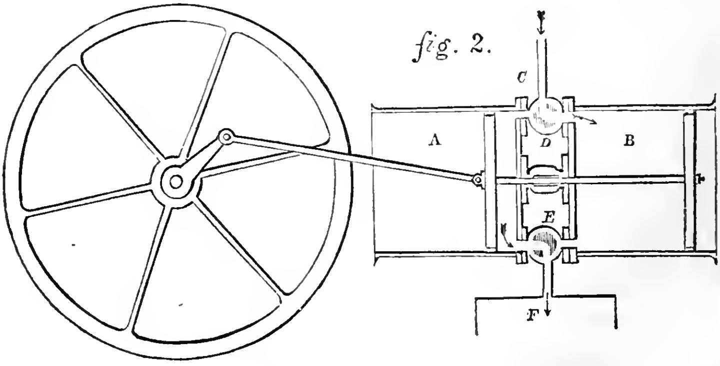
There are other points which need not be dwelt on here. They may be placed in separate rooms or buildings, and if in such cases the steam and atmospheric piston cannot be relied on to move simultaneously, the steam may be discharged into a receiver, from which the atmospheric cylinders might draw it.

Waste steam from other sources may thus be converted into power.

If the proposed system did not harmonize with the exhaustion of both forces it could not be the true one, but the fact is patent that it does, for the more dilated the vapor before condensation the more facile its conversion into water. It has never been decided where the line of pressure should be drawn between condensing and non-condensing engines in order to give the best effect to the former. European engineers place it quite low, while here it has been run up to what has been thought too high. Now, the truth is there is no such line, for the results of condensation keep pace with the direct force, whether that be of five or fifty atmospheres—another proof that the system is what it is claimed to be. It completely *reverses* the hypothesis, "the greater the pressure under which steam is raised the less is to be gained by its condensation." That may possibly apply to superheated steam. It is perfectly true of our condensing engines, from which it was deduced.

Fig. 2—a mere variation of the preceding one—will serve to show how the proposed plan comprises the exhaustion of the *expanding* as well as the contracting force. This has hitherto been deemed unattainable, and, but for the system of condensation in separate cylinders, it would still be an impossible problem.

fig. 2.



The cylinders, A, B, are horizontal, and both pistons attached to one rod, which passes through a stuffing-box connected to the closed ends of the cylinders. C supplies the waste steam; D, a valve or three-way

cock, communicating with C and A, B; E, a similar one, with passage from the cylinders to the condenser, F. Suppose the steam cylinder (not represented) working with steam of 60 lbs on the inch, its piston half the diameter of A and B, and with the same length of stroke. The arrows indicate the passage open between A and the condenser, and steam passing into B, against whose piston it acts in unison with the atmospheric pressure moving forward the piston of A. Thus the steam in B keeps expanding *with the receding piston* till its force expires at the end of the stroke. The valves are then reversed, and the same thing takes place in A.

Let experience determine the difference between engines on this plan and those of Hornblower and Woolf.

fig. 3.

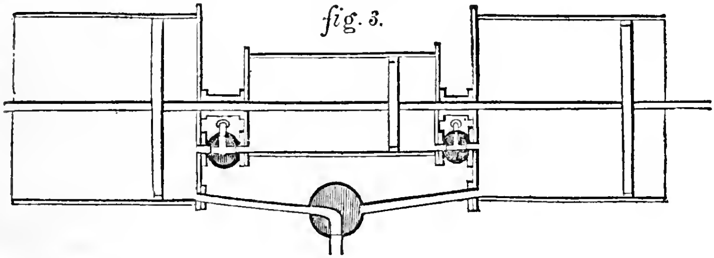
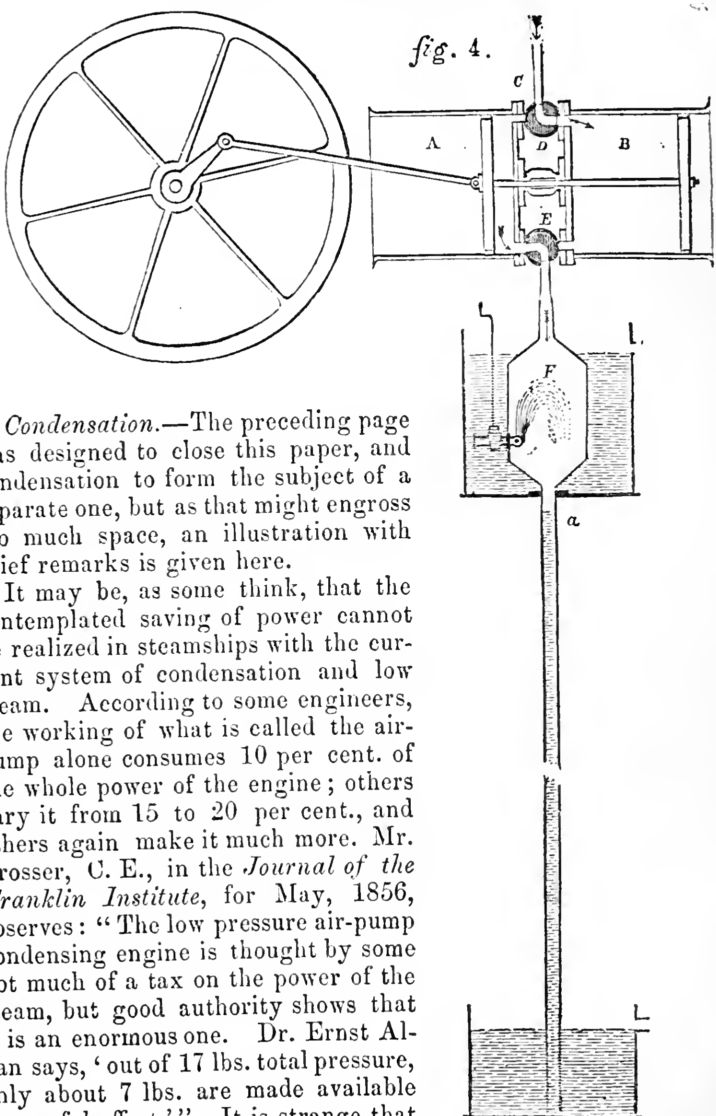


Fig. 3, outline of an engine in which the steam and atmospheric cylinders are combined. To engineers details are unnecessary. The steam cylinder is placed between and on a line with the atmospheric ones, and connected directly with them. The three pistons are on the same rod —the steam and exhaust valves, and stuffing-boxes—as in Fig. 2. By such an arrangement side-pipes are got rid of, and also the additional waste of steam for "clearance," there being no chance for water remaining in the cylinders to arrest the pistons.

There are those who question the *rationale* of the popular cut-offs. If no more steam enter a cylinder than sufficient to overcome the resistance, it matters little whether it enters at once or flows in to the end of the stroke. In the latter case, the motion is equable, and the engine not strained by varying the momentum. Hence, the alleged gain, it is said, can only be the per centage of power unnecessarily employed at the first part of the stroke. Leaving the question for others to settle, it is enough to observe that by using steam as here proposed, expansion may be carried to an extent that will, in a great measure, if not wholly, supersede the use of cut-offs. No power can be lost by their non-usage.

fig. 4.



Condensation.—The preceding page was designed to close this paper, and condensation to form the subject of a separate one, but as that might engross too much space, an illustration with brief remarks is given here.

It may be, as some think, that the contemplated saving of power cannot be realized in steamships with the current system of condensation and low steam. According to some engineers, the working of what is called the air-pump alone consumes 10 per cent. of the whole power of the engine; others vary it from 15 to 20 per cent., and others again make it much more. Mr. Prosser, C. E., in the *Journal of the Franklin Institute*, for May, 1856, observes: "The low pressure air-pump condensing engine is thought by some not much of a tax on the power of the steam, but good authority shows that it is an enormous one. Dr. Ernst Alban says, 'out of 17 lbs. total pressure, only about 7 lbs. are made available for useful effect.'" It is strange that an *experimentum crucis* has not put an end to such diversity of opinions on a matter so important. If any such have been made I know not where to look for them. I cannot, however, resist the conviction that a thorough investigation will lead, sooner or later, to the abandonment of "low" steam.

It is proposed to maintain the vacuum by the same power that acts upon it—by connecting the condenser with a pipe having a perpendi-

cular descent of about 36 feet; its lower end dipping into water in a vessel containing somewhat more than sufficient to fill it. See fig. 4. The vacuum resembles that in the cylinder of a suction-pump, placed too high for the weight of the atmosphere to raise water into it. Whatever amount of condensation takes place in the condenser, the length of the liquid column will continue the same, its upper surface never rising above *a*, however copious the liquefaction of the steam. The vapor evolved in the vacuum from so small a surface will be insignificant, and may be reduced, or its evolution checked, by a stratum of oil, which could be but slowly dissipated, as there is no escape for it except by descending through the entire length of the pipe.

The air contained in the water would, of course, not be thus got rid of. For that purpose a syringe or small pump would be required. Suppose the amount, as some assert, 5 per cent. of the water injected, hardly 5 per cent. of the force now expended on the withdrawal of it and the water could be wanted.

The temperature of water in present condensers is sometimes as high as 120°, the vapor from which has a back pressure of between 3 and 4 inches of mercury; and when the pressure in the boiler is 37 inches, the loss of power is one-tenth. By the plan here sketched no water collects in the condenser, and the temperature, when water is abundant, may be reduced to 80°, and with ice still lower.

For stationary engines there can be little difficulty in providing for the pipe's descent. When located on ground floors in cities there are cellars and often under-cellars, and in the country wells are common. The pipe itself need not be vertical, provided the requisite depth is secured.

It is proper to state that this mode of maintaining the vacuum is not a new conception. It was proposed in Arnott's Physics many years ago, but is supposed never to have been put in practice. An adaptation of the principle to marine engines would be of surpassing value, nor does there appear an insuperable difficulty in giving to the condenser, at least in some cases, a sufficient elevation above the engine.

But one resource more appears open to reduce the enormous force expended on condensing machinery, and that is to use ICE as the cooling agent for the reasons assigned in the first part of this paper, (p. 207, vol. xlix.) That something approaching to two-thirds of the water now required, and, with it, a like proportion of the power would be dispensed with, need not be questioned. Instead of the water in steam requiring twenty times as much for condensation, Mr. Sewell, C. E., declares, in his article on "Surface Condensers," *Jour. Frank.*, vol. xliv, p. 348, "that more than double the amount is sometimes necessary. The quantity of water necessary to condense a certain quantity of steam varies as the temperature thereof, the colder the water the less quantity is necessary, being from fifteen to *forty-five times* that contained in the steam. . . . . To relieve the engine of this enormous load, it is found to be of advantage to use less injection water to condense the

steam, and consequently get less vacuum, the loss of power from this cause being less than when the air-pump is overloaded."

Another advantage of ice for internal condensation arises from the fact that "air combined with ordinary water is discharged in the act of freezing." Hence, there will be little to pump out.

To prevent premature condensation in the cylinders A B, besides enveloping their exterior in non-conducting wrappers, I would introduce into them cylindrical linings of vulcanized rubber, as already suggested: (page 208,) molded on polished cores they are comparatively inexpensive.

To conclude: If it be a truism that the two forces—expansion and contraction—bear the same relation as action and reaction, ignoring the latter in our high pressure engines, and then turning to account little over half of that, reflects no credit on us. The blunder cannot, we believe, be tolerated through another generation, although there are some who consider the proposition to reduce the loss of power, by making two-thirds available in place of one-third, as bordering on the chimerical, as if the elements to accomplish what is proposed were lacking—as if the saving of that which is palpably thrown away was impossible and the attempt preposterous. Economists, to scraps, of wrought and unwrought materials we are wholesale spendthrifts of that which gives value to them. Our engines will certainly be referred to hereafter as characteristics of the dawn, or early days of steam power. If the plan here suggested to improve them be deficient, as it well may be, let others be tried till success is attained, for progress is certain, and though it depends on steam it can never lack those who are keen to detect and resolute to remove obstacles in its path; who, to use a Scriptural phrase, press onward to perfection, by casting off things that are behind (the age), and reaching out to those that are before.

P. S.—In the present condition of national affairs a brief allusion to a kindred topic may be permitted. Our planet is a school for engineers, as for other professions. It is alive with illustrations of mechanical laws, as fixed and immutable as the universe itself; and nothing is more certain, that only so far as our devices accord with them can they succeed. Thus it will be, as heretofore, with the propelling blades of a steamer as with the force that propels them. Abortive *must* be all attempts to make her speed what it ought to be as long as the principle of *form* so distinctly and variedly manifested in organisms that move rapidly through air and water is ignored. It is fundamental. No finite intelligences can improve or supersede it. There is marvellously more in it than common observation perceives. It governs other attributes. Endless are the projects on minor points, and all of them fruitless for lack of that which only can give value to any. An increased speed of three or four knots would have virtually ended this horrible war two years ago, saved thousands of lives, and multiplied millions of money. It may just as well be attained as the current rates of speed, and it will be, though apparently not without some further struggling against a plain law of physics—plain and perfect to

those who look into it, a stumbling-block and foolishness to those who do not.

Every horizontal section of a blade has a different velocity, and, to make the resistance and effect uniform, its width must *diminish with the dip.* The centre of resistance, instead of being near the extremity, will then be drawn in towards the centre of the blade, and economy of force will result. There is, in fact, a reciprocal influence pervading every part, every feature and movement of a perfect blade; and wherever this harmonious action does not exist, loss of speed and waste of power are and will forever be inevitable, for physical laws are eternal. There are some things which the present state of the arts cannot accomplish, but there is no physical obstruction whatever to our giving to sea-boats a maximum speed with a minimum of force—to rivalling in this respect the ablest engineers of the future. *

On Certain Methods of Treating Cast Iron in the Foundry. By ZERAH COLBURN.

From the Lond. Civ. Eng. and Arch. Journal, May, 1865.

The short notice given me for the preparation of this paper, together with the fact of my almost constant engagements, must serve to excuse any apparent haste in the treatment of the subject, as well as the absence of diagrams. I had thought of writing upon iron founding, and, to a certain extent, I have done so, but the term "iron founding" would hardly include some things of which I shall now speak, and hence I have chosen the title already announced.

Beginning with the plant of the foundry, something may be said of the cupolas and of the blast apparatus. The cupola furnace is still much the same as described by John Wilkinson, who patented it in 1792. His smelting furnace (and smelting is from the Dutch word *smelten*, signifying melting only, and not necessarily the extraction of ores) was, to use his own words, "made very low, about 10 feet high, of cast iron plates bolted together and lined with fire-brick." A strong blast was introduced through one, two, or more tuyeres. In 1820, one William Taylor patented the use in blast furnaces of several tuyere holes, at various heights and in different sides of the furnace, for the admission of the blast to insure its equal distribution. The same idea is, of course, equally applicable to cupola furnaces, to which it has been applied by Mr. Ireland, of Manchester, in his "upper tuyere" furnace. That there is any real advantage in the upper tuyere furnace is still denied by some of those who have used it, and it is difficult to say wherefrom any substantial advantage should result. One of Mr. Ireland's cupolas, measuring 4 feet in diameter outside and 22 inches in diameter in the hearth or crucible, has 3 tuyeres of 6 inches diameter, and about 20 inches above these 8 tuyeres $2\frac{1}{2}$ inches in diameter. A strong blast has much more influence than the subdivision or distribution of the blast, and we know that in blast furnaces enormous masses of ore, coke, and limestone are penetrated by a blast of moderate pressure from a few tuyeres arranged in a single row around

the hearth. In the United States a number of cupolas have been made of late years and used with considerable success, with an annular opening or port $\frac{3}{4}$ of an inch to 2 inches wide, around the whole inner circumference of the furnace, and with some of these furnaces with which I have had to do, their horizontal section was elliptical, measuring 9 feet by $3\frac{1}{2}$ feet internally; and with a blast equal to $10\frac{1}{2}$ inches of water, or $\frac{3}{8}$-pound per square inch, they brought down 12 tons of iron per hour. The full charge was 21 tons, which could always be brought down in 2 hours after turning on the blast, the annular tuyere or port being nearly 20 feet in length around the furnace, and $1\frac{1}{4}$ inch wide, although a large part of this great tuyere area of, say, 2 square feet, is obstructed by the charge in the furnace itself. Had I time to do so I should have been glad to have prepared diagrams of these cupolas from the working drawings in my possession. The elliptical section of furnace was adopted many years ago in cupolas in some of the German iron foundries, and it was revived in Alger's blast furnace, of which a good deal was heard in England about eight years ago. It cannot be asserted that this has any advantage, while it clearly has certain disadvantages in increased surface and cost of construction. The object sought in the elliptical furnace is that of containing a large charge with but a moderate distance between the opposite sides of the furnace, but here an increased pillar of blast will fully compensate for any increase of distance from the tuyere to the centre of the charge.

I have always believed that a decided advantage would result, in the case of cupolas, by having the drop bottom in general use abroad. I doubt if there are a dozen cupolas in America with the irremovable bottom as adopted in English practice. The severe labor in raking out the bottom of an ordinary cupola would be saved by the drop bottom, where the mere withdrawal of the bolt sends whatever is in the furnace into a pit below. The American cupolas are built upon a cast iron base ring, which is supported upon three cast iron columns, at a height of, say, 2 feet above the foundry floor. This base ring is of the external diameter of the cupola, say, 5 feet, and in its internal diameter is that of the circular trap door known as the drop bottom. The trap door will be, say, 2 feet in diameter, $1\frac{1}{2}$ inch thick, and having a coombing 4 inches high carried around its upper edge to receive a paving of fire-clay or a round fire-clay tile to support the charge. In my own practice, I have hinged this door by $1\frac{1}{2}$-inch hinge bolt, 28 inches long, with a stout head at one end and a cotter in the other; the lugs or ears in the door and in the base ring were each 4 inches long, and of good thickness. The door was held up by a draw bolt, passing through staples of great strength in the base ring, the bolt being of 3 inches by $1\frac{1}{2}$-inch iron. It is often said, "What if such a trap door should give way, with from three tons to ten tons of iron in the cupola?" Such accidents never happen, nor would they be attended with any great danger if they did happen. The iron might be lost, but that would be the worst of it. To shut the trap door a stout wrought iron stalk descends from its centre for 18 inches, a heavy ball being fixed upon the end of this staple. A chain is attached to this ball,

and the drop or trap can be thus easily moved by hand when the draw bolt is out.

After the cupola an improvement is desirable in the blast apparatus. The rotary fan is in almost universal use in foundries. In order to obtain a pressure of 20 inches or 24 inches of water, with 3 square feet of tuyere opening, a 3-feet Lloyd's fan is usually driven at from 1500 to 1800 revolutions per minute, the tips of the vanes moving, say, at the rate of nearly 3 miles per minute. From fifteen to eighteen horse power are required, and with an old-fashioned fan much more. Besides the power there is to be considered the wear and tear of straps running at a high velocity. For considerable pressures of blast, to which foundry practice is tending, the direct compression of the air by a piston is more economical than the fan blast. For a blast furnace, of course, no form of fan would be practicable at even a pressure of $2\frac{1}{2}$ pounds per square inch, still less at 5 pounds to 6 pounds, as is occasionally employed. I have seen a steam blowing engine used with excellent results in a large foundry where the air cylinder was in a line with the steam cylinder, both the steam and the air pistons being fixed to the same rod, while a pair of connecting rods worked a fly-wheel to carry the engine over the centres. The same class of blowing engines, working at an air pressure of from 15 pounds to 20 pounds per square inch, is now employed by Mr. Bessemer in blowing air into his converters. For more moderate pressures, however, a rotating apparatus is preferable. In gas-works, where the difference of pressure in the retort and in the purifyers is, perhaps, 1 pound per square inch, it is usual, in the London works at least, to employ Beale's exhausters. No gas engineer would think of employing a fan for exhausting. Mr. Beale's exhauster is constructed somewhat upon the principle of a rotary pump, patented by the late Mr. Siebe, a father of the present Mr. Siebe, in 1828. This pump has been reproduced in the States as Cary's pump, and it was the water-pump adopted in the American steam fire-engine exhibited in the International Exhibition of 1862. An almost identical machine for pumping air instead of water, is now in extensive use in American iron foundries under the name of M'Kenzie's blower. Many of my friends who have used these blowers prefer them to fans, as taking less power, while they are, of course, capable of working at any pressure of blast required. One of those blowers, now at work at a locomotive factory of which I was engineer in 1854, is 26 inches in diameter, 3 feet 6 inches long, and at a speed of 100 revolutions per minute, blows against a pressure of 21 inches of water in supplying a large cupola. The power required is found to be much less than that consumed by a fan, especially at high pressures, while the wear of straps is very moderate, the lineal rate of the driving strap being now about 300 feet, instead of something like a half a mile a minute, as with a fan.

I shall devote the further portion of the present paper to the consideration of—1. Means for increasing the strength and hardness of castings. 2. Means for insuring uniform cooling in castings after pouring. 3. The treatment for malleable castings. 4. Chilling.

At one time, when cast iron was employed for boilers, shafting, large ordnance, and bridges, its strength was of great consequence. It has now become usual to employ wrought iron or steel for the applications just named, and, indeed, wherever great absolute strength is required. Even engine beams, since the lamentable failure at Hartley, are being made of wrought iron. So the importance of great strength in castings has no doubt been lessened; and for most purposes it has been found cheaper to employ a somewhat larger quantity of ordinary iron than to pay a higher price and incur the delay often attending the search for a superior quality. For many purposes, indeed, as in engineer's tools, a liberal allowance of metal is requisite to secure stiffness,—a kind of stiffness better provided in such cases by inertia, or mere dead weight, than by the absolute resistance of the metal per square inch. Yet there are still purposes, as in the case of railway chairs, water pipes, columns, &c., without mentioning hydraulic press cylinders and steam cylinders, where great strength in cast iron is of much importance; and cast iron is still the material principally employed in America for cannon of 13-inch, 15-inch, and in recent instances even 20-inch calibre. This is not the cast iron, however, of which guns have long been made in England, and were it not indeed greatly superior to our own, it would never withstand the proof and service charges which the heavy ordnance in question is known to bear. The report of the chief of ordnance in the United States Navy gives the service of one of the 15-inch cast iron guns as follows: It was fired 900 rounds with a 440-pound solid shot. The charge of powder, at first 35 pounds, was successively increased to 50 pounds, 60 pounds, and 70 pounds. With 60-pound charges 220 rounds were fired, and the gun only burst with a 70-pound charge and 440-pound shot at the end of 900 rounds. It is doubtful if even as good results have been, or will be, attained by the most carefully wrought iron guns of the same calibre. Upwards of 100 of these 15-inch guns are now in service. Before going on with the consideration of how such great strength in cast iron is attained, it may be as well to give the following notes of the 20-inch cast iron guns, of which a number have already been made. They weigh $51\frac{1}{2}$ tons each, and the first of these guns was 13 days in cooling. They are 20 feet $3\frac{1}{2}$ inches long over all, and 17 feet 6 inches long in the bore. Their greatest diameter is 5 feet 4 inches. They are fired with 100-pound charges of powder, and a solid shot weighing 1000 pounds.

I shall say nothing of the selection of particular brands of iron, nor of the great importance of proper mixing in the cupola, for I could only say, what every qualified founder well knows, that upon these a great deal depends. I could give no direction better than those upon which founders now act, each having to choose and mix the irons which he has found best for his own purposes in his own district, for it is always important to him not to send further than is necessary for his pigs. But there are modes of increasing the strength of a large number, if not all, of the irons known to commerce, and although there is still much doubt as to the relations between the chemical constitu-

tion and the strength of iron, it is certain that all the known modes of strengthening cast iron are modes whereby its proportion of uncombined carbon and of silicium is known to be diminished. If we puddle cast iron up to a certain extent, and stop at the right point, we have steel of very great strength, and if we carry the puddling far enough we have wrought iron. So if we melt cast iron with wrought iron, as in making what is called Stirling's toughened metal, we lessen the relative proportions of the impurities to the iron as contained in the pig, and if we do not get a remarkably tough metal, we, at any rate, produce one of great hardness, and some of our locomotive makers employ such a mixture purposely to obtain hardness in their steam cylinders. So also, by oxidizing cast iron at a high heat, as in the treatment for malleable iron castings, we gain undoubted strength and toughness. Here, too, the carbon and silicium of the iron are lessened in quantity, and so it may be apprehended that they are by the American practice of remelting all the iron employed for cannon and keeping it for some time in fusion. This practice at one time went so far as three and even four remeltings, the iron being kept in the fluid state for three hours at each melting. In this way the tensile strength of iron, ranging from 5 tons to $6\frac{1}{2}$ tons in the pig, has become 9 tons at the first casting, and after remaining in the melted state for two hours, 13 tons at the second casting, and $15\frac{1}{2}$ tons per square inch at the third casting, the period of fusion at each melting being from one to three hours. The final strengths thus reached are very great, in one case reported by Major Wade, of the United States Ordnance Board, a tensile strength of $20\frac{1}{2}$ tons per square inch of cast iron having been obtained. The American ton is generally 2000 lbs., but the strengths I have quoted are in tons of 2240 lbs. These great tensile strengths do not appear, however, to give a tough metal, using the term tough to express the product of the cohesion and extensibility of the iron. It was found that, in employing iron having an average tensile strength of 38,000 lbs., or 17 tons per square inch for 8-inch guns, they burst at the seventieth or eightieth fire, while 10-inch guns, made from iron having a strength of 37,000 lbs. per square inch, burst at the twentieth round. This was known in 1851, and in the following year, at the Tredegar Iron Works at Richmond, Virginia, where I was then engaged, and which was one of the leading foundries for supplying cannon to the United States government, a return was made to iron of a strength of 30,000 lbs., which, having more elasticity, as it was then thought, gave a really stronger gun. It has since been ascertained that the real fault with the stronger iron was that it contracted more in cooling, and as insufficient provision was made for equal contraction throughout the casting, the guns of strong iron were thus under great initial strain from their own shrinkage. This very strong gun iron contracts generally $\frac{3}{16}$ths of an inch per foot in casting. The driving-wheels of American locomotives are of cast iron, and when, in 1851, to secure greater strength against breakage, gun iron of a strong quality was experimentally used, it was found that the wheels broke worse than ever, as they were strained to a great

extent by their own shrinkage before they came out of the foundry. This gun iron is simply the better classes of iron mixed and melted in an air furnace, the cupola never being used for guns, as indeed it never ought to be used for any castings intended to have great strength, on account of the over-heating of portions of the metal and the direct action of whatever sulphur may be contained in the coke. In the Bessemer process, where the exclusion of sulphur is so important, the pig metal is for this reason melted in a reverbatory furnace, or air furnace, as it is sometimes called.

Now, as all the processes whereby cast iron is strengthened are processes whereby its proportion of contained carbon and silicium is diminished, some quicker and much cheaper mode of effecting this object is required than that by remelting or by partial puddling. This quicker and cheaper mode would be had by a partial application of Mr. Bessemer's treatment, that is, by blowing air through the iron for perhaps three or four or five minutes, instead of twenty. But, it will be asked, if you are to have the Bessemer apparatus at all, why not convert the iron at once into steel? There are several reasons why we should not. To make steel, a much higher quality of iron, and generally the addition of spiegeleisen, is necessary. As steel, the metal cannot be run into goods, but only into an ingot, which requires very heavy hammers to forge it, as well as machine tools of unusual strength to finish it after forging; the wear of the converter and other plant would be much greater for steel than for toughened iron. The waste of metal before the finished article, whatever it might be, could be produced, would be greater for steel than for cast iron. I have recommended this partial application of the Bessemer process, and I believe that when more attention comes to be given to strength in castings, this treatment will be adopted. The apparatus for carrying it out would be exceedingly simple, and would be worked with but little trouble, a blast being derived from the rotary blower already described.

But absolute strength in the iron of large castings is of little consequence unless they cool, after pouring, in such a manner as not to leave them subject to considerable internal strains. We know that the late Professor Hodgkinson found that with the iron he experimented upon the compressive strength was six times that in tension, and hence that the bottom flange of a cast iron girder should have six times the sectional area of the top flange. But very few, if any, engineers adopt such a proportion, as the casting would, in all probability, crack in cooling. Most of my audience have seen the cast iron bridge over which the London and North-Western Railway crosses the Regent's canal. The first girders for this bridge were cast at the Tinsley Park Works. The iron made there was very hard; and I have been told by my friend, Mr. Shanks, who was engaged there at the time, that it would chill to a depth of two inches. It was used, among other things, for making rollers to roll steel. The Regent's canal bridge drawing was sent down there, and they made the patterns and cast the girders. They broke through and through in cooling. Then

they altered the patterns ; and by pulling off the sand from the thicker portions of the castings, so as to equalize the cooling, a number were cast with the loss of one out of every six. At last, six were sent up to London ; and of these every one broke in a thunder storm. Other girders were then cast of different form. Castings, over-strained in cooling, are apt to break even under a moderate degree of vibration ; and the late Mr. Rastrick, once of the Bridgenorth foundry, and afterwards engineer-in-chief of the London and Brighton Railway, once stated in evidence how a number of cast iron boilers he had made cracked open after a peal of thunder.

I have seen, and so, no doubt, have many others, a railway wheel cast in a chill, and which, on being taken from the mould immediately after pouring, broke in two within a quarter of an hour. And, if the experiment were made, there is not the least doubt that a heavy gun, pulled out of the sand as soon as the metal had set, and then finished, would burst at the first round. The outside would cool first, compressing the liquid iron within. This, cooling afterwards, would pull away from the iron already set around it—or, if it did not actually separate, the strain of contraction would be such that the gun would be ready to crack as soon as it was violently disturbed. An unannealed glass tumbler is as good a comparison as any. The old-fashioned playthings, Prince Rupert's drops, illustrate the same effect of internal strain due to unequal cooling, glass being particularly brittle in this respect, in consequence of its low conducting power, and from its having no ductility when cold.

To make a casting of great strength it is necessary that all parts cool alike or nearly so. In the case of guns cast solid, the core bored out is often found honey-combed by retarded cooling ; and the metal forming the surface of the bore can be proved to be under considerable initial strain in consequence. Of course, guns were cast hollow many years ago; but not until 1847 was it proposed to cool the core, after casting, by means of water circulating in pipes within it. Captain Rodman, in that year, patented the mode by which all the larger American guns have been cast. Within the core are two water pipes, one inside the other, and like those in Mr. Field's boiler, known to so many in this society. Water flows down the inner pipe, which is open at both ends, and rises through the outer pipe, which is closed at the bottom. A perfect circulation of water is thus secured. In casting one of the 20-inch guns, February 11th, 1864, water was thus run through the core for twenty-six hours, at the rate of thirty American gallons per minute for the first hour, and sixty gallons per minute for each subsequent hour, equal to 341 tons of water in all. The iron was considered of too hard a quality to be further cooled by water, and for the next twelve days air was forced down the bore of the gun at the rate of 2000 cubic feet per minute. During the first hour after casting, the water flowing in at 36°, came out at 92°. During the second hour, with twice the quantity of water flowing through, it came out at 61°. In other cases, in casting 10-inch guns, as much as 700 tons of water have been run through the core, the water-cooling

occupying four days, or nearly 100 hours. In some of these cases, a fire was made at the bottom of the gun-pit, and continued for sixty hours, the outer iron casing of the gun-mould being kept at nearly a red heat for the whole time. It is by these means that all parts of the gun are cooled alike, or nearly so, and, with iron of a tensile strength of, say, 13 tons per square inch, that such great endurance has been attained in firing.

Nearly all the railway wheels in use on the American lines are of cast iron, chilled on the periphery. It is not merely that these wheels are cheap, but they are preferred to the wrought iron wheels as used on English railways. I am not now speaking of the engine driving wheels, but of the carriage and wagon wheels, of from 2 ft. 6 ins. to 3 ft. in diameter, although the size is very seldom greater than 2 ft. 9 ins. The cast iron wheels run until they are worn out, and they wear for a long time; whereas the wrought iron wheels require frequent turning, and, still worse, their flanges soon become worn so thin as to become unsafe, a fact due, perhaps, to the inferior condition of the American lines. It was, however, a long time before the American founders could produce chilled wheels which should be safe under all circumstances; and when it is remembered that they are now employed as the leading wheels of the heaviest express engines working on lines, of which, what we should call the ballast, is sometimes frozen as hard as a rock for two or three months in the year, and in a climate where the mercury is occasionally from 10° to 20° below zero, or 40° to 50° of frost, and when it is added that these wheels do not break oftener than wrought iron wheels on the best English lines, it must be added that they are as safe as anything can be. In this I am speaking from my own knowledge, extending over a period of ten years, during the whole of which time I was closely connected with the leading American locomotive factories and lines of railway. The founders had to obtain not merely strong iron, in respect of tensile strength, but an iron of considerable toughness, and, besides, an iron that would chill well. As a rule such iron is only obtained by careful mixing; and it must be sought by long and costly experiment. I do not doubt that iron for excellent chilled wheels, if they were ever required, might be found in England; but I would not run the risk of saying what mixtures would produce it, although I should say Blænavon cold blast and the Forest of Dean irons would enter into such a mixture, with a little iron like that made at Tinsley Park for hardening. The chief difficulty with the American founders was that presented by the unequal contraction of the wheels in cooling. At first the wheels were made with spokes, but as the rim was quickly cooled in the chill, thus compressing the still fluid iron in the nave, which subsequently contracted away from the rim, it was necessary to divide the nave radially into two or more portions, and to afterwards fill the openings thus made in the nave with lead and antimony, a pair of stout wrought iron rings being shrunk over the ends of the nave, to compress it properly upon the axle. But it happens in the case of spoke wheels cast in a chill, that, from the greater quantity of iron at the ends of the spokes,

the chill is softest there, so that the tread of the wheel wears into as many flat spots as there are spokes. This is one of several reasons why the disk form is to be preferred for chilled wheels, but there was the difficulty of providing against their unequal cooling. The disk being whole or undivided, the nave had to be left whole also; and so, unless the disk could yield laterally during cooling, or unless the whole wheel was cooled uniformly, a great strain would result in the disk and rim. So the disks were dished, or curved in cross-sections; indeed the variety of form to be found in the earlier chilled wheels of the disk pattern was something remarkable. At last, one of the leading founders, Mr. Whitney, determined to try the effect of equal cooling. He cast his wheels solid, as the others had done, but with a single and perfectly flat disk, stiffened by straight or radial ribs at the back. Such a wheel, pulled out of the flask when red-hot, and thrown out to cool in the open air, would crack open in a few minutes. Mr. Whitney, however, took his wheels from the flasks as soon as the iron had set, and lowered them at once by machinery into a deep pit made in brick-work, and which had previously been heated as hot as the wheel itself. The pit being filled with wheels placed one above the other, and separated by iron rings, was closed air-tight, and left with its contents to cool. The cooling occupies three days; and it is therefore so much slower than the progressive conduction of the heat from one part of the wheel to another, that all parts must cool absolutely alike. The result is that the wheels thus annealed may be so nearly cut open, by a turning tool in a lathe, as to leave but a thin film of iron connecting the boss and the rim, and yet, until struck with a hammer, the nearly separated portions do not come apart. The chill appears to take place at the moment when melted iron meets the iron-mould; and the heat of the annealing kilns does not affect the hardness of the chill in the least degree. Mr. Whitney's wheel factory in Philadelphia is the largest and best fitted in America; and his wheels, made and cooled as just described, are in use throughout the States; and are preferred to all others, even to the best English made wrought iron wheels, a number of which by the Lowmoor Company were put in use on the Hudson River Railroad in 1851, where the flanges of the tires soon came to cut so thin under the constant wriggling of the bogies or truck frames, that they had to be soon replaced with chilled wheels. Although we are considering the improvement of castings generally, I have dwelt at some length upon these wheels, because, from their severe service and the improvements made upon them, they illustrate in a convincing manner the importance of equal cooling. I wish it to be quite understood that I refer to chilled wheels only as an illustration, and however well they answer their purpose in America, I am not recommending their adoption here. But I am certainly of opinion that, in the case of many castings, especially those of irregular form and those of great size, their strength would be doubled were they properly cooled; and it is more from the want of precautions in cooling than from any inherent untrustworthiness in cast iron itself, that it has come to be regarded with doubt for purposes requiring great strength.

The next point to be considered is the treatment for making castings malleable. I should have said nothing of this were it not that, although exceedingly simple, it is but very little understood, for it is a very common notion that many and curious "chemicals" are required, and there is much mystery in the process. Making iron castings malleable was indeed among the lost arts, and old records show that it was lost and rediscovered more than once. The French philosopher Reaumur, who wrote upon it 140 years ago, observed that it was then practised as a great mystery in Paris. At last chemistry came to the aid of the metal worker, and he learned that what he had so long called sulphur in the iron—and sulphur was once a name applied to many substances—was really carbon, the same as charcoal or diamond. And chemistry showed how carbon would always forsake iron for oxygen, and that cast iron, treated with oxygen, was made malleable, as it always is, whether in the old refinery fire, in puddling, in pig boiling with forge scales and refinery cinder, in the Bessemer process, and in still other modes of treatment. In 1804, Samuel Lucas, of Sheffield, turned this knowledge practically to account. He took out his patent, too, and described his improvement very cleverly; and, to put it in the fewest words, it was nothing more than the present process of making castings malleable by roasting them, at a high heat, for from 72 to 120 hours in powdered hematite iron ore, or in any metallic oxide. The oxygen of the ore unites with the carbon in the iron casting, which, being thus left without carbon, becomes malleable—malleable, indeed, to a remarkable degree. It is commonly said that castings intended to be malleableized should be from very hard, brittle iron. It is not exactly because a casting is a brittle that it is of the best sort for the malleable iron treatment, but brittle castings contain less carbon than those from grey iron, and so the malleable process does not have to be so long continued to get rid of it. To those who are not accustomed to consider all forms of iron and steel as combinations merely of iron and carbon in different proportions, there is something a little paradoxical in the fact that a grey iron containing much carbon is tough; a white iron, containing less carbon, is brittle; steel, containing still less carbon, is also brittle; while wrought iron, containing but little carbon, is very tough. Even to a chemist these facts are not easy to be explained; nor shall I examine them further here, it being sufficient merely to have shown why a white and brittle cast iron, such as some of the Ulverston iron of which clock bells are made, is the best for the malleable iron process, because it contains less carbon than a grey iron. The castings must be packed perfectly air-tight in layers of ore, and shut up in cast iron boxes, of which the joint should be luted. The natural ore used for purifying gas at the various stations of the chartered gas works would, no doubt, answer very well for malleable castings, although it cannot be said whether Mr. Hill's oxide would do as well. The goods should be heated very gradually, twenty-four hours being occupied in getting up, and twenty-four hours more in letting down the heat, besides the two or three days at full heat. The heat should be very even over

all parts of the goods, and while the full heat is on it should be kept constant by careful firing and attention to the draft. The iron ore may possibly fuse upon the surface of the casting, thus covering it with lumps or warts; but this is the result of too high a heat, or access of air. Oxide of zinc, which is abundant in some parts of America—as near New York—is preferable to iron ore, but those who cannot obtain the former can get on very well with the latter. The agricutural implement makers have turned the properties of malleable cast iron to good account for the tines of their cultivators. At the large works of the Messrs. Howard, of Bedford, unusually large pieces are made malleable by roasting in hematite ore. McHaffie's malleable castings made in Glasgow—and for which it is generally supposed that there is a patent, although I believe there is none—are no doubt made in much the manner described, as also, no doubt, are Crowley's, of Sheffield, although different makers add various chemical substances, which may act in the same manner as the iron ore, and thus, to a certain extent, replace it, although it is doubtful if they greatly promote its real action. Wherever a shape can be easily made in wrought iron, this is probably cheaper than a malleable casting, and it is doubtful, therefore, whether the latter will ever be extensively used. It may be added that the tensile strength of malleable castings varies according to their size, and the depth to which the decarburization extends. If they were freed of their carbon all the way through, they would be converted into wrought iron, or, say "homogeneous metal," as the softest kind of steel has been called. So much of the casting, however, as is not decarbonized by the malleable iron treatment, remains cast iron, and has only the strength of cast iron. The effect of the process is generally visible for only a small depth below the surface, but small malleable iron castings have borne a tensile strain of 50,000 ℔s. per square inch.

On the last point named in the earlier portion of this paper—the production of chilled castings—there is not very much to be said. It is for the founder to ascertain, from his practice and from such experiments as he is in the best position to make, which irons will chill, and which will not. Of those that will chill, it is important, if the chilled casting have to be put under great strain, that the chill be well blended with the softer iron, instead of their being a distinct line of demarcation. It may be that the best application for chilled castings will be that for chilled shot, which, at far less cost, comes nearest to steel. To cast shot in chills, with the best results, it may be found best to subject the iron, just after pouring, to a considerable steam pressure. By simple mechanical arrangements, easily devised, a pressure of 100 ℔s. of steam per square inch, equal to a column of iron upwards of 30 feet high, could be turned instantly upon a casting just poured into a chill mould. The effect would be to secure greater density and uniformity in the casting, and to render it stronger for its purpose. It is well known that "head," or a high rising column of metal over the mould, is an important matter in making strong castings, and that, in some cases, as in casting sugar mill rolls, this head

or "gate" of metal is well churned by manual labor. There can be no doubt that steam pressure would answer the purpose still better, nor that the best mode of applying this pressure might be easily determined.

The very cheapest applications of iron are in its condition of cast iron. For some purposes, as for heavy ordnance, it is questionable whether cast iron is not really equal to wrought iron and steel. It is certain that comparatively little has been done in this country to improve the strength of large castings, and that, in some cases, wrought iron has been adopted, without sufficient attempts to meet the requirement with a much cheaper and more adaptable material. It cannot be argued that, in arched bridges like some of those now erected and in course of erection over the Thames, wrought iron is equal to cast iron in its resistance to compression. It is probable that absolutely better and cheaper structures could be put up in cast iron. It is to be hoped that the careless practices which formerly prevailed of casting large pieces on the foundry floor, and of paying little attention to uniform cooling, have not permanently deprived us of one of the best applications of one of the most important materials of construction.

For the Journal of the Franklin Institute.

Notes of Shipbuilding and the Construction of Machinery in New York and vicinity.

Continued from vol. xlv, page 382.

The Steamer Neptune.—Hull built by Van Deusen Brothers, New York. Machinery constructed by Henry Esler & Co., Brooklyn, L. I. In government service. Owners, United States Government. Original owners, Neptune Steamship Company.

Hull.—Length on deck, 218 feet. Breadth of beam, 35 feet 8 inches. Depth of hold, 12 feet 4 inches. Depth to spar-deck, 19 feet 10 inches. Draft of water, 13 feet. Frames, molded, 16 inches, sided, 8 to 10 inches, apart at centres, 24 inches. Four athwartship bulkheads. Rig, schooner. Tonnage, 1341 tons, O. M.

Engines.—Vertical direct. Diameter of cylinders, 44 inches. Length of stroke of piston, 3 feet.

Boilers.—Two, tubular, located in hold. Fire surface, 4·580 square feet. Grate surface, 144 square feet. No blower to furnace.

Propeller.—Hibsch's patent. Diameter, 12 feet. Pitch, 20 feet. Material, cast iron.

Remarks.—The floors of this vessel are filled in solid for 100 feet. The keel is of white oak, sided, 14 inches, molded 24 inches. Put together in two pieces, each 12 inches in thickness, with 4-inch coatings, and thoroughly fastened with galvanized iron bolts. The stern is of white oak, naturally carved, sided, 13 inches, and molded, 15 inches outside of rabbet. The floors are of white oak, double, sided 8 inches, well bolted together, and square forward. The side and centre keels are 14 by 14 inches, and fastened with yellow metal. The bottom planks are $3\frac{1}{2}$ inches thick, increasing near the wales to 4

inches. The deck planking is of thoroughly seasoned white pine, 3 inches thick and 6 inches wide, fastened with two 6-inch galvanized spikes in each beam, and two 5½-inch spikes in each carling. The cross timbers are of solid white oak and yellow pine, 10 inches thick, and of an even depth with the keelsons.

Her masts are 78 and 81 feet in length, and 24 and 34 inches in diameter.

The engine department of this vessel is well fitted in every respect, especial care being taken that all articles were of first quality.

The Steamers *Nereus*, *Glaucus*, *Proteus*, and *Galatea* are sister vessels to the *Neptune*, built at the same time, and are also owned by the U. S. Government.

The Steamer Golden City.—Hull built by Wm. H. Webb, New York. Machinery constructed by Novelty Iron Works, New York. Superintendent of construction, Captain Francis Skiddy. Route of service, Panama to San Francisco. Owners, Pacific Mail Steamship Company.

Hull.—Length on deck, 340 feet. Breadth of beam, 45 feet. Depth of hold, 23 feet 6 inches. Depth to spar-deck, 31 feet. Draft of water, 17 feet. Frames, molded, 15 inches, sided, 18 inches, apart at centres, 36 inches. Four athwartship bulkheads. Rig, brig. Tonnage, 3336 tons, O. M.

Engines.—Vertical beam. Diameter of cylinder, 105 inches. Length of stroke of piston, 12 feet. Diameter of piston-rod, 11½ inches. Diameter of crank-pin journal, 14 inches. Length of do., 18 inches. Diameter of beam-centre journals, 15 inches. Length of do., 21 inches. Fitted with a Sewell's condenser, having 5500 brass tubes, 9 feet long, the condensing surface of which is 8000 square feet.

Boilers.—Martin's horizontal tubular, placed in a nest. Diameter of face, 20 feet 4 inches. Depth, 11 feet 6 inches. Height, 11 feet 6 inches. Diameter of smoke-pipe, 10 feet. Each boiler has five furnaces. Fire surface in each, 3·379 square feet. Grate surface, 120 square feet.

Water-wheels.—Diameter outside of buckets, 40 feet. Length of buckets, 18 feet. Width of do., 2 feet. Diameter of water-wheel shaft journal, 22 inches. Length of do., 30 inches.

Remarks.—This noble vessel is built of white oak, hacmetac, &c., and square fastened with copper and treenails. Around her frames extend iron straps, diagonally, and double laid, 4½ by ⅞-inches. Every precaution that could be taken was resorted to in the construction of this steamer, that she should be a vessel of comfort and safety. Her model is almost faultless and she is very fast. Her interior is designed with great skill and care for the comfort of passengers and with a keen perception of the beautiful. Under her deck it is very roomy, and not cut up with band-box saloons, like most of our ocean steamships. Her upper and main saloons are very large, accommodating from 1500 to 2000 passengers.

The Steamer James T. Brady.—Hull built by Thos. Stack, Brooklyn, L. I. Machinery constructed by Fulton Iron Works, New York. In Government service. Owners, Arthur Leary & others, New York.

Hull.—Length on deck, 213 feet. Breadth of beam, 30 feet. Depth of hold, 9

feet. Draft of water, 7 feet. Frames, molded, 12 inches, sided, 6 inches, apart at centres, 26, 28, and 30 inches. Rig, none. Tonnage, 585 tons, O. M.

Engines.—Vertical beam. Diameter of cylinder, 45 inches. Length of stroke of piston, 11 feet.

Boiler.—Tubular. Length, 24 feet. Width, 13 feet. Fire surface, 3000 square feet. Grate do., 86 square feet. No blowers to furnace.

Water-wheels.—Crooker's adjustible. Diameter, 27 feet 2 inches. Face, 8 feet. Dip, when loaded, 3 feet.

REMARKS.—This vessel is of white oak, &c., and copper fastened. Iron straps extend around her frame ; they are $3\frac{1}{2}$ by $\frac{3}{8}$-inches. She is supplied with an independent steam, fire and bilge pump, bilge injection, and valves to all openings in her bottom. She has given satisfaction to those connected with her.

The Steamer Ajax.—Hull built by C. & R. Poillon, Brooklyn, L. I. Machinery constructed by C. H. DeLamater, New York. Superintendent of construction, John Baird. Route of service, Pacific Ocean. Owners, Wakeman, Gookin & Dickinson, New York.

Hull.—Length on deck, 224 feet. Breadth of beam, 35 feet 8 inches. Depth of hold, 18 feet 6 inches. Number of decks, 3. Draft of water, 16 feet. Frames, molded, 14 inches, sided, 9 and 8 inches, apart at centres, 26 inches. Floors filled in solid under engines. Rig, brigantine. Tonnage, 1357, O. M., 1355, N. M.

Engines.—Horizontal. Diameter of cylinder, 54 inches. Length of stroke of piston, 4 feet 4 inches.

Boilers.—Two, return tubular. Located in hold. Each boiler has 224 tubes, 10 feet long by 3 inches diameter.

Propeller.—Of Baird's design. Diameter, 13 feet 6 inches. Material, cast iron.

REMARKS.—This ship was built with the greatest care, both as regards materials and workmanship, the materials being of white oak, hacmetac, and locust; diagonally braced with iron straps $4\frac{1}{4}$ by $\frac{5}{8}$-inches, laid double, extending from floor-heads to upper deck, connecting with longitudinal iron bands running from stem to stern. The deck-beams are of Georgia pine and Maryland oak ; the ceiling in the wake of machinery, of Georgia pine ; the bottom plank is of white oak ; the water-ways of white pine, and the topsides are built in hull. The fastenings used in her construction are yellow metal, copper, iron, and locust treenails.

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*The Steamer Golden Rule.**—Hull built by Henry Steers, Greenpoint, L. I. Machinery constructed by Morgan Iron Works, New York. Route of service, New York to Aspinwall, C. A. Owners, M. O. Roberts & others.

Hull.—Length on deck, 310 feet. Breadth of beam, 44 feet. Depth of hold, 12 feet. Depth to spar-deck, 25 feet. Number of decks, 3. Draft of water, 14 feet. Frames, molded, 17 inches, sided, 15 inches, apart at centres, 32 inches. Four athwartship bulkheads. Rig, foretopsail schooner. Tonnage, 3080, O. M

Engine.—Vertical beam. Diameter of cylinder, 31 inches. Length of stroke of piston, 12 feet.

Boilers.—Two, flue. Located in hold, and use a blower.

Water-wheels.—Diameter, 30 feet. Material, iron.

REMARKS.—This is a very fine vessel, being built of the choicest white oak, hacmetac, &c., fastened in the securest and most durable

* Ran on a coral island in the Carribean Sea, May 30, 1865, and was lost.

manner, and fitted with all the conveniences and comforts a vessel of her class requires. Her bottom planks are of white oak, 4 or 5 inches thick, and her keelsons are of white oak and yellow pine. The *Golden Rule* has made several runs on the route of her service, giving satisfaction to owners, builders, and passengers.

The Steamer Gen. Barnes.—Hull built by Lawrence & Foulk, Greenpoint, L. I. Machinery constructed by Morgan Iron Works, New York. Route of service, New York, Havana, and New Orleans. Owner, H. T. Livingston.

Hull.—Length on deck, 230 feet. Breadth of beam, 35 feet. Depth of hold, 18 feet 6 inches. Number of decks, 2. Draft of water, 11 feet. Two athwartship bulkheads. Frames, molded, 16 inches, sided, 9, 10, and 12 inches, apart at centres, 28 inches. Rig, foretopsail schooner. Tonnage, 1348 tons, O. M.

Engine.—Vertical beam. Diameter of cylinder, 60 inches. Length of stroke of piston, 10 feet.

Boilers.—Two, flued. Located in hold. Do not use blowers.

Water-wheels.—Diameter, 26 feet. Material, iron.

Remarks.—This steamer is of white oak, chestnut, &c., and square fastened with copper and treenails. Around her frames, which are partly filled in solid, extend iron straps, 4 by $\frac{5}{8}$-inches, diagonally and double laid, increasing their strength. She is fitted with pumps, injections, bottom valves, &c., as vessels of her class are required to be. Her passenger accommodations are excellent, and in every respect this steamer ranks well.

The Steamer City Point.—Hull built by Geo. Greenman & Co., Mystic, Connecticut. Machinery constructed by James Murphy & Co., New York. In Government service. Owners, James Murphy & Co. & others.

Hull.—Length on deck, 203 feet. Breadth of beam, 30 feet. Depth of hold, 9 feet 6 inches. Number of decks, 1. Draft of water, 7 feet. Frames, molded, $12\frac{1}{2}$ inches, sided, 6 inches, apart at centres, 26 inches. Rig, none. Tonnage, 555, O. M., 1110, N. M.

Engine.—Vertical beam. Diameter of cylinder, 45 inches. Length of stroke of piston, 11 feet.

Boiler.—One, tubular. Located in hold. No blowers to furnaces.

Water-wheels.—Diameter, 27 feet. Material, iron.

Remarks.—This steamer is of white oak, chestnut, and cedar, and square fastened with copper and treenails. She is strapped with iron straps, $3\frac{1}{2}$ by $\frac{1}{2}$-inches., and her bottom is coppered. Her water-wheel guards extend fore and aft and are half sponsoned.

The Steamer New York.—Hull built by Jeremiah Simonson, Greenpoint, L. I. Machinery constructed by Allaire Works, New York. Route of service, New York to Aspinwall. Owner, Commodore C. Vanderbilt.

Hull.—Length on deck, 300 feet. Breadth of beam, 42 feet. Depth of hold, 26 feet. Number of decks, 2, Draft of water, 15 feet. Frames, molded, 18 inches, sided, 10 inches, apart at centres, 30 inches. Rig, foretopsail schooner. Tonnage, 2551, O. M.

Engine.—Vertical beam. Diameter of cylinder, 90 inches. Length of stroke of piston, 12 feet.

Boilers.—Two, tubular. Located in hold. No blowers to furnaces.

Water-wheels.—Diameter, 25 feet. Material, iron.

REMARKS.—This steamer is of white oak, locust, &c., and is square fastened with copper and treenails. Her floors are filled in solid. Iron straps diagonally and double laid, 5 by $\frac{7}{8}$-inches, extend around her frame, and in other ways she is constructed in the most approved manner. Her bottom is coppered, and she is furnished with pumps, injections, and cocks to all openings.

The Steamer Shamrock, now the Gunboat Isnomia.—Hull built by Thomas Stack, Brooklyn, L. I. Machinery constructed by James Murphy & Co., New York. Original owners, Arthur Leary and others.

Hull.—Length on deck, 211 feet. Breadth of beam, 27 feet 6 inches. Depth of hold, 9 feet 6 inches. Number of deck, 1. Draft of water, 5 feet 6 inches. Frames, molded, 12 inches, sided, 6 inches, apart at centres, 26, 28, and 30 inches. No rig. No bulkheads. Tonnage, 585, O. M.

Engines.—Vertical beam. Diameter of cylinder, 45 inches. Length of stroke of piston, 11 feet.

Boiler.—One, tubular. Located in hold. No blowers to furnaces.

Water-wheels.—Diameter, 28 feet. Material, iron.

REMARKS.—This vessel is of white oak, chestnut, and hacmetac, and is square fastened with copper, iron, and treenails. She is strapped with iron straps, 3 by $\frac{7}{16}$-inches, and her bottom is coppered. She has knees under her main deck, and is considered a fine steamer. The speed shown by her in her trial-trip induced the Navy Department to purchase her, and fit her for blockading duty. E. M. B.

(To be Continued.)

For the Journal of the Franklin Institute.

Work and Vis-viva. By JOHN W. NYSTROM.

My "masked battery" opened upon Professor De Volson Wood, of the University of Michigan, appears to have had a greater effect than was anticipated, and I can well afford to slacken my fire, although unaware of my "vulnerable points," which, he says, "cannot stand a fierce assault." It is not necessary to reply to the greater part of Professor Wood's last article, lest the discussion degenerate into a useless squabble. I shall therefore confine myself to the important points, with a view to clear up the confusion which still pervades the questions of power and work, inasmuch as he yet seems to maintain the old stereotyped error that "power is the work done in a unit of time."

The number which expressed the work done in a unit of time, will be equal to the number which expresses the power in operation, but that does not prove the two quantities to be alike.

Six cubic feet and six square feet, although identical in number, do not prove that a cubic foot is a square foot, merely because their numbers are alike.

Professor Rankin and others also say that "power is the work done in one minute," which is substantially the same as saying that a square foot *one foot thick* is a cubic foot.

Professor Wood further remarks: "Again, he (Mr. Nystrom) says F V T is the expression for work. Now, if T = one second, minute, or hour, do we not have F V = *the work* which is done in a unit of time?" Here it is necessary to resort to the elementary, and inform Professor Wood that T does not disappear in the formula for work, merely because it equals one or the unit, for on his reasoning we may set F = 1, and the work will be = V T = S the space, which is equally absurd. It will first be necessary to explain the difference between addition and multiplication.

When a quantity is multiplied by an abstract number, it will not change the *nature* of that quantity, but the product will be the same as the sum of so many concreate quantities added together; but when a quantity is multiplied by another quantity, the product becomes a third quantity different from the two first.

Let two square feet, for example, be multiplied by the abstract number three, and the product will be six square feet, or the sum obtained by adding together three times two square feet, which will also be six square feet; but if two square feet be multiplied by a *thickness* of three linear feet, the product will be six cubic feet, which is radically a different quantity from two square feet, or from three linear feet, which constitute its elements.

Professor Wood, however, in his examples above quoted, confounds specific or concreate quantities, such as time and velocity, with abstract numbers.

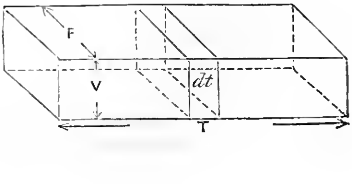
Power F V = F V×1 the abstract number, and

Work F V T = F V×1 minute, or whatever time or unit of time is a specific quantity.

Professor Wood quotes my statement that *power is the differential of work*, and says: "Do we not rightly infer from this that power is a part of work, an infinitessimal portion of it, and hence of the same kind as work?"

In answering this question it will be best to refer to a parallelopipedon, by which work has before been illustrated.

Let the accompanying cubic figure, F V T, represent the work, then the cross section F V represents the power, and F V dt the differential work. Now let us diminish dt until it becomes infinitely small, say = 0; then the solidity of the differential work F V dt = F V × 0 = 0, or there will be no solidity, or no work, whilst the quantity F V, which represents the power, is unchanged.



It may please Professor Wood better to say that "power is the differential coefficient of work."

I trust this will satisfy him that power is not the work done in a unit of time, and that the English unit for power is not a unit for work.

The popular expression "force of momentum" is perfectly correct. It does not mean that momentum is force, but that force is an element of momentum; same as we say, "the length of a rectangle" or "the surface of a solid." The momentum divided by time is the *force of momentum.*

It is to be regretted that in the conclusion of his article he "will pass over many important points," for the object of our discussion ought to be to reveal the subject, not to conceal it. I am, as Professor Wood has remarked, "a truth seeker," and think it unkind of him to "pass over important points."

The *Scientific American* says: "The main purpose of Mr. Nystrom seems to be to deny the position that work is independent of time, and he succeeds in involving the question in considerable confusion." After which, the editor of the *Scientific American* suggests to "free our minds from confusion" by taking "most important steps to use words always in their exact signification," *par example.* "Regarding work as the overcoming of physical resistance, it is plain that the aggregate amount of any given quantity is independent of the time required for its performance." Does not the *Scientific American* here convey the idea that *work is independent of what it requires,* namely, the time? The editor evidently means to say, that "a given quantity of work may be performed in any desired length of time," but he does not seem to conceive that the *work is dependent on whatever time required for its completion.*

On Aniline Black. By M. Lauth.

From the London Artizan, March, 1865.

Aniline black is a new colored derivative of aniline, which, so to say, completes the series of brilliant colors derived from this base. It differs, however, in many respects from the other colored derivatives. The mode of production, the way of fixing it on fabrics, and the insensibility to physical and chemical agents which it presents are points on which it differs essentially from the red, blue, and violet of aniline. Mr. Lightfoot's process, which the author quotes, is well known to our readers, and we shall only quote from this paper the author's new process for aniline black, which, it will be seen, and, indeed, is admitted to be, but a simple modification of Mr. Lightfoot's. Mr. Lauth's process consists in printing with the mixture of hydrochlorate of aniline and chloride of potassium an insoluble oxidizable salt, which will become soluble on the fabric—sulphide of copper, for example. By the oxidizing action of the chloric acid (or the chlorine which is set free by the reaction of hydrochlorate of aniline on chlorate of potas-

sium), the sulphide of copper is transferred into sulphate. In this same process, some of the disadvantages of Mr. Lightfoot's process are avoided. It is more economical, the mixture does not act on the steel rollers, nor does it weaken the fabric—not more, at all events, than madder black. The color is very permanent and is fixed at from 20° to 40° C. Its composition allows of its being printed with all sorts of colors. Aniline black has a specially beautiful appearance. It has a very rich black, velvety look. It is completely insoluble in water, alkaline, or acid, and is not affected by soap. Acids change the black to green, but the original color is restored by an alkali. Bichromate of potash deepens the shade, but a very strong solution slightly reddens it. Strong chloride of lime bleaches it, but the color returns after a time. M. Lauth promises another and further account of analine black in a short time.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, June 15th, 1865.

The meeting was called to order, with the President, Wm. H. Sellers, in the chair.

The minutes of the last meeting were read and adopted. The minutes of the Board of Managers were also reported, including the following resolution:

Resolved, That a book be prepared by the Secretary, in which any member of the Institute may enter the titles of such works as he deems desirable additons to the library, from which the library committee shall make such selections as they may deem expedient; and that the President be requested to call the attention of the members to the book at the next meeting of the Institute.

The following donations to the library were also reported: From the Royal Astronomical Society, the Institute of Actuaries, the Statistical Society, and the Society of Arts, London; the Natural History Society of Montreal, Canada; Prof. De Volson Wood, Ann Harbor, Michigan; Hon. Wm. D. Kelley, U. S. Congress, and Frederick Emmerick, Esq., Washington, D. C.; and from the American Philosophical Society, John F. Houston, Esq., Prof. John C. Cresson, Prof. John F. Frazer, Samuel S. White, Esq., the Schuylkill Navigation Company, B. H. Bartol, Esq., and the Board of Health, Philadelphia.

The minutes of the standing committees were then reported. The committee on weights, measures, and coinage was, on motion of Mr. Coleman Sellers, discharged. The committee on steam expansion reported progress.

The paper announced for the evening, by Theodore D. Rand, was then read as follows:

The Occurrence of Petroleum in Canada.

Petroleum is found in Canada in geological formations lower than

in any other region yet discovered. The lowest worked oil bearing stratum is the corniferous limestone of Enniskillen.

Geographical Position.—On an island near Great Manitoulin Island in Lake Huron a spring of petroleum flows from the Trenton formation. At Pakenham, C. W., the cavities of large orthoceratites in the same formation contain it in considerable quantity. The same rocks are found to contain oil at Cape Gaspé.

T. Sterry Hunt, *Journal of Science*, vol. xxxv., page 168, has described a very interesting development of petroleum in Canada which throws some light on the vexed question of the origin of the oil.

In a quarry of corniferous limestone in the township of Bertie, on the Niagara River opposite Buffalo, are seen massive beds slightly inclined, composed of a solid crystalline encrinal limestone, which appears destitute of petroleum, and owing to the presence of water impermeable to it. In some of these beds are large corals of the genus Heliophyllum, the pores of which are open but contain no oil. Two beds, however, one of three and one of eight inches, which are interstratified with these, are in great part made up of species of Heliophyllum and Favosites, the cells of which are full of petroleum. This is seen in freshly broken masses to be absent from the solid limestone which forms the matrix of the corals and resembles in texture the associated beds. As the fractured surfaces of the oil bearing beds become dry the petroleum spreads over them. A thin continuous bed of Favosites is met with, which is white, porous, and free from oil, though beds above and below are filled with it. The facts observed here appear to show that the petroleum, or the substance which has given rise to it, was deposited in the beds in which it is now found at the formation of the rock. We may suppose in these oil-bearing beds an accumulation of organic matters whose decomposition in the midst of a marine calcareous deposit has resulted in their complete transformation into petroleum which has found a lodgement in the cavities of the shells and corals immediately near. Its absence from the unfilled cells of corals in the adjacent and interstratified beds seems to forbid the idea of the introduction of the oil by distillation or infiltration.

Although petroleum has been found in these and many other less important localities over a wide area in Canada, there is but one county in which it has been sufficiently developed to make it of commercial importance, or to entitle it to the name of an oil region. This is Lambton County, C. W.

This county lies near the centre of the western part of the peninsula formed by Lakes Erie and Huron and the St. Clair River. The river Thames runs through this peninsula, following nearly the course of an anticlinal axis, stated by Logan to extend from the northwestern part of Lake Erie to the southwestern part of Lake Ontario. Wells have been recently put down along the Thames at Bothwell, in Zone township, with considerable success. The central and most important point, however, lies about 18 miles northwest of Bothwell at Oil Springs, in Enniskillen township. There wells have been sunken and immense quantities of oil obtained. The surface of this region, unlike that of

the Pennsylvania and West Virginia regions, is a perfect level, hollowed out to a depth of twenty to thirty feet by the largest streams, but without the slightest apparent undulation. A vast forest of large trees, oak, elm, beech, walnut, ash, hickory and basswood covers the soil everywhere. Six miles north of Oil Springs is Petrolia, where also several wells have been sunk.

The town of Oil Springs has sprung up in a very short time. It contains about one thousand inhabitants, several hotels, good stores, two churches, and a school house, besides refineries, blacksmith and cooper shops, &c. It is connected with Wyoming, a station on the Great Western Railway twelve miles north of Oil Springs, by a plank road, and by a similar road also with Sarnia, (on the St. Clair River opposite Port Huron, Michigan,) which is 18 miles northwest.

History.—Oil springs were known to exist in this vicinity at a very early period. There were chiefly three: one at Petrolia, one or more at Oil Springs, where in addition the dried up petroleum forms two "gum beds," as they are termed, of some acres in extent, and in the township of Mosa on the Thames.

These gum beds consist of a deposit from an inch to some feet in thickness, of a bitumen hard in winter, but becoming soft though not fluid in summer. It is generally mixed with vegetable matter, but sometimes is nearly pure.

In 1861 numerous wells were sunk, many through the surface clay only, others one or two hundred feet in the rock. Oil was everywhere obtained in fair quantity. During the winter of 1861–62, and the following spring, the great flowing wells which have made this region so famous were struck one after another. The yield from these was enormous, ranging by estimate from 1000 to 7000 barrels a day. This enormous supply brought down the price to ten cents a barrel at the wells, and of course rendered all the pumping wells worthless for the time being. The shipments of oil over the Great Western Railway for six months ending January 31, 1862, were 6246 barrels, while for the six months ending January 31, 1863, they were 57,550 barrels. In 1863 these wells ceased flowing and became filled with water.

The pumping wells had mostly been abandoned, and through careless tubing and neglect, had caved and ceased to yield oil when again examined. The machinery at all of them was of the rudest possible kind, constantly getting out of order.

In 1864 several companies were organized for petroleum mining in this district. They have gone to work in a thorough manner, with proper derricks and machinery, and soon will be in a position to test thoroughly the oil value of the region.

Geology.—The surface stratum of this region is a clay, probably of the drift period, containing fragments of limestone, and occasionally well preserved shells. This is from thirty to eighty feet in thickness. Through this the surface wells are sunk, which have yielded largely. The clay from a depth of sixteen feet near the gum beds contains oil in fissures. Under this throughout the whole region is the corniferous limestone. Between the two in Enniskillen and its vicinity, occur

shales of the Hamilton group, from 100 to 200 feet in thickness; and where these shales are absent and the limestones covered by the clay only, the rock, though impregnated with petroleum and pierced by springs yielding it, as at Oxford and Mosa, does not yield it in paying quantities. The shales seem to have served as barriers to prevent the exudation of the oil. The strata met with in boring are as follows:

Clay (with sometimes gravel), ...	30 feet to 80 feet.	Drift.
Shale (sometimes absent), ...	0 " " 100 "	Hamilton.
A soft clay shale (called soapstone), . .	60 " " 80 "	
Limestone, ...	3 ins. " 6 "	
Soft clay shale, ...	10 feet " 15 "	
Limestone, ...	15 " " 30 "	
Soft clay shale, ...	15 " " 30 "	
Limestone (not bored through), . . .	350 " " unknown.	Corniferous.

The softness of the shale gives rise to frequent cavings where wells are not properly tubed.

The Wells.—The following are the most important wells in this region. We give the local estimates of past yields:

Concession II. Lot 17, Enniskillen. Fairbank's Well. This yields about 60 barrels a week at the present time, and nearly all of it during the last three days of the week. None of the wells are pumped on Sunday. It is stated that when this well was pumped after a stoppage of about a month, hardly any oil was obtained for three weeks; the pump yielding abundance of water, with but a fraction of oil; and even now, after the stoppage over Sunday, the yield on Monday is almost all water; but the proportion of oil daily increases until on Saturday it sometimes reaches forty barrels, with comparatively little water.

Con. II. Lot 18. Shaw & Bradley Wells. These wells when first struck yielded by estimate 2000 barrels each per day. They were soon tubed, and the flow shut down to 400 or 500 barrels a day for about a year, when the flow ceased. The Shaw well flowed a full stream of pure oil from a pipe 2½ inches in diameter.

Con. I. Lot 18. Black & Madison Well. This is one of the most famous wells, and is frequently called the Bruce Well. It is 35 feet to rock, 237 feet to oil vein, and 27 feet below it. Nothing unusual was observed until the pumps had been worked for a short time, when suddenly the oil and gas burst forth, throwing the pump out of the well, which spouted oil like a fountain, 7 or 8 feet high, for 40 hours. Its supposed yield was 7000 barrels a day; and the ground is said to have been covered a foot deep with oil. Indeed the trees and stumps for some acres around it bear marks of the oil upon them with a regularity that nothing else could have produced. This well has been purchased by the Little Falls Company. Near it is a natural spring of oil, and two other wells, one of lubricating, the other of rock oil—such are here the distinctive designations.

On the same lot was the Phero well. This spouted up three or four feet from the mouth of the conductor, which was six inches square, and yielded some three thousand barrels a day for three or

four days, when it was shut off, and not opened for three or four months, when it failed to flow.

A surface well on this tract, sunk a few feet in the rock with crowbars, yielded by pumping with a spring-pole, 6000 barrels, at the rate of 30 or 40 barrels a day. There were in all 27 flowing wells, all of which were within a square mile. No wells except those at Petrolia were bored outside of an area about two miles square until recently.

While these wells were flowing, immense quantities of oil flowed down the creek and were lost. Several times it took fire on the creek, and blazed above the tops of the tallest trees. Evidence of this is even now to be seen in the track of the creek, marked by a border of lofty forest trees charred to their very summits, those further off being charred on the creek side only, and those a little further off uninjured.

At Petrolia, six miles north, is the only well in the region now flowing. It flows six or seven barrels a day, and has done so for three or four years quite steadily.

The present yield of the whole region is small. This is in great part due, as has been stated, to the abandonment of wells and unskilful pumping. Many of the wells were sunk by men of small capital, who, even if able to finish the well, were not able to erect proper engines and pumps. The machinery is, in almost all cases, very defective, and it is probable that the present engines, properly geared and with proper pumps would greatly increase the yield of oil.

The Oils.—The lubricating oil is of very good quality, commanding \$12 per barrel in gold. The rock oil is heavy, containing little or no benzine, and has a peculiar and offensive odor. It is this odor which, without due care, creeps into the refined oil, that has given the Canada oil a bad reputation; but oil is now being produced that equals in all respects the best Pennsylvania. This odor seems to be due in part to a volatile sulphur compound. Some of the wells discharge sulphuretted hydrogen gas, and the same gas is given off during distillation. There are a number of small refineries both at Oil Springs and at the towns along the Great Western Railroad. The largest and best in the region is at Petrolia.

Paraffine.—We believe that there is yet to be in this region a great manufacture of paraffine. The crude oil contains very little benzine, the absence of which diminishes its value, but some 10 per cent. of paraffine can be obtained from it in the winter at little expense, and without injury to the other products. This manufacture, now attracting much attention in England, is comparatively new here, and has not been as successful as we think it must be in the future—not alone for the manufacture of candles, for which it is so admirably suited, but also for other purposes, in which its indestructible properties will make it in time almost invaluable. As a varnish for metal work exposed to the air or to corrosive vapors, it has no equal, for it is entirely unchanged by acids or alkalies, lengthened exposure to the air, or indeed by anything except high heat. Already a pa-

tent has been taken out for preparing wooden vessels to hold petroleum or benzine, by filling the pores of the wood with paraffine; and it is very probable that barrels lined with it might be used, with certain precautions, to contain acids, &c., in place of the present expensive and fragile glass carboys. The crude paraffine can be manufactured and delivered in Canada at 10 or 15 cents a pound, and afford a fair profit to the refiner. It is not difficult to purify, and there seems to be no good reason why it should not be thrown into the market purified, either in mass or as candles, at 20 or 30 cents a pound, instead of 50 to 75 cents, its present price, in which case it would soon supersede all other candles.

Point Gaspé.—There is another point in Canada, to which allusion has heretofore been made, which has recently attracted attention as a promising oil field. This is near Point Gaspé, on the Atlantic Ocean, at the mouth of the St. Lawrence.

Public attention was first drawn to this by the geological report of Sir Wm. E. Logan, published by government in 1863. At page 402, of this report, he says: "There is still to be described the Greenstone dyke, connected with the southern anticlinal at Tar Point. This dyke is of a dark grey color, weathering to a rusty red, and is traversed by numerous horizontal and vertical joints, and abounds in large and small druses. . . . . . These cavities are filled with petroleum. This, in some instances, has hardened to the consistence of pitch. The peculiar odor of this substance, which has given the name of Tar Point to the locality, may be perceived at a distance of fifty yards.

Two petroleum springs occur along the line of this anticlinal. One of these is on the south side of the St. John's River, about half a mile above Douglastown. Here the oil oozes from the mud and shingle of the beach. The other is on a small branch of Silver creek, six or seven miles from Gaspé basin. The rock adjoining the dyke is a sandstone, but it is not improbable that here, as in Canada West, the source of the oil may be in the fossiliferous limestone beneath.

About a mile and a half south-east of Gaspé basin is found a layer of inspissated petroleum, resembling on a small scale the gum beds of Enniskillen, while to the eastward the soil is saturated with petroleum. Many other indications in the same neighborhood are enumerated.

The fossiliferous limestone spoken of belongs to the Lower Helderberg group, which lies at the summit of the Silurian rocks, and below the corniferous, the oil-bearing rock, of the Enniskillen region. It is about 2000 feet in thickness, and is frequently impregnated with petroleum, the surface of the country is mountainous, and deep valleys, both longitudinal and transverse, frequently occur.

No wells having yet been sunk in this region, it cannot yet be placed among the oil-producing districts; but the indications are certainly sufficient to warrant the sinking of a few wells to test the matter, for the very advantageous location of the region as regards the European market, and the abundance of wood for both barrels and fuel, would make a well of but small yield very profitable.

After the reading of this paper some questions were asked and answered as follows:

Prof. Rogers.—I would like to ask Mr. Rand whether there are any indications in this region of a material which might serve the purpose of asphalt. That which comes from Cuba has been used for a great variety of purposes, but has been restricted in its application by the expense of getting it; but in engineering operations it is an important and valuable material, and if it occurs in the oil regions in the West, it will be a source of great revenue to the people. I was not aware that it was found in this country till petroleum was discovered.

Mr. Rand.—My only personal knowledge of it has been in connexion with the gum beds of Canada West. This material is closely allied to asphalt, but whether it could be obtained pure from vegetable matter, I question. I would ask how the asphalt of Nova Scotia would compare with that of European or Cuban?

Prof. Rogers.—I have not seen the material itself, and dont know how it compares with that which is used in Europe, which is the Swiss asphalt, which occurs there in the limestone formations. It has been used in making roads, by breaking the rocks quite small, then heating it, and, while hot, laying it on the road-bed prepared with gravel, and rolling over the whole heated iron rollers; these rollers are heated by the roadside in furnaces provided for that purpose. It has been found that the material has been rendered sufficiently soft to adhere very well to the road. This mode of road-making is a great deal cheaper than the regular asphalt road, and much more durable, and can be repaired much more easily. In repairing, all they have to do is to place some more heated material where required, pass the redhot roller over it, and it forms a neat, durable road. Asphalt has been used for roads in France for many years, and in Paris, and the pavements in front of the Bourse, opera houses, and theatres are all of asphalt, which makes a very smooth road, curiously enough, not slippery. This article has also been used in covering the backs of arches to prevent the percolation of water and the formation of incrustations found on the interior of almost all the railway arches.

It has an extensive use in engineering, and it is desirable to have it accessible in large quantities in this country. The Cuban material is quite expensive, and that which comes from Switzerland must also be from the distance which it must travel to reach this country.

Mr. Rand.—I presume the largest quantities of that kind are found in California.

Mr. Chase.—What is the difference between the gum beds and the asphalt?

Mr. Rand.—The asphalt is a resinous substance, breaking with a clean fracture. The gum beds do not seem to have this pure resinous appearance, but are very much mixed with vegetable matter, so much so that it is not a sample of true asphalt. It is a mixture of the inspissated petroleum with vegetable fibres, twigs, grasses, and other matters, and seeming to have been a slow accumulation on the surface of the ground.

The thanks of the society were then tendered by the President to Mr Rand, after which was read in its order the

Secretary's Report.

Civil and Mechanical Engineering.—We would call attention, in the first place, to several papers of great ability, which have appeared in certain journals, and which, though too extensive in their scope for a full notice in this place, are well worthy the examination and study of those among our members who may be interested in the subjects handled.

The first of these is a paper read before the London Institution of Civil Engineers, March 14, by Mr. J. W. Barzelgette, on "The new System of Drainage in London, the general Principle and History of Construction." (*Newton's London Journal of Arts*, vol. xxi, page 287.)

The second is a paper read before the same society by Daniel Miller, Esq., on "Structures in the Sea without Coffer-dams."

This essay treats chiefly of such structures when made of "beton" or concrete, *i.e.*, a mixture of hydraulic lime and broken stone or the like.

Among the remarkable applications of this material enumerated, we find the construction of the government docks at Toulon. In this case, great troughs, as large as the proposed docks, were formed of beton deposited in the sea and allowed there to harden. When the sides of these were finished above the water line, they were emptied by pumps, lined and finished within with stone, and provided with caissons at what were intended to be their entrances, after which the parts of the beton wall in front of these caissons were removed, leaving the docks complete.

Again, at Genoa, the mole was extended by the use of "beton," thrown into the sea from baskets, behind a light boarding to give it shape.

Yet again, at Algiers an immense breakwater was constructed of beton, in blocks of about 30 tons each, some formed "*in situ*" by filling wooden cases without bottoms, and removing the case when the interior material had set, and others made on land in similar cases and "launched" into the sea when finished. These blocks, after many years' exposure, show no signs of "wear," even at their angles and edges.

It is further stated that the Pont de l'Alma over the Seine, is built (arches as well as piers) of this material. (See *Civ. Eng. and Arch. Journal*, May, 1865, page 133.)

Lastly, we would call attention to the article on "The Treatment of Cast Iron in the Foundry," which will be found in full at another page of this *Journal*.

A bridge is proposed to carry the Great Western Direct Railroad across the Severn, which will be the largest bridge yet built. Headway, 122 feet; longest span, 600 feet, (150 feet more than the Menai bridge.)

As much as 40 tons of rust have been removed from the Menai and

Conway bridges, in cleaning their tubes. This does not speak well for their durability.

On account of unexpected difficulties, it is now computed that the Mount Cenis tunnel will occupy ten instead of five years in its execution.

Self-moving steam rollers are now used in Paris to consolidate the macademized roads, with a saving, it is stated, of 60 per cent. as compared with the ordinary rollers drawn by horses. The whole machine weighs 17 tons. This weight bears upon two cast iron rollers, so geared as to turn in a circle 45 feet in diameter.

There are now running in Paris 143 of Lenoir's gas engines. One of these is also in this city and will be exhibited before the Institute at the next meeting, (*i. e.*, in September.)

In a paper read before the London Society of Arts by F. A. Paget, on the "Wear and Tear of Steam Boilers," attention is directed to the fact that the shape of a boiler has a great influence upon its durability, in a sense not generally realized. Thus a boiler of an elliptical section will, under pressure, tend to assume a cylindrical form and settle back to its original shape on relief of the strain. The frequent repetition of this action will cause a deterioration of structure, and even a scaling off on the surface at the points of greatest tension. Such an action could not, of course, occur where the section of the boiler was circular. This and other facts mentioned in the essay above noticed, are worthy of attention. (See *Mechanics' Magazine*, 1865, page 261.)

Our attention has been directed to a machine for breaking hemp, invented by Joseph H. Siddall, of Shoemaker's Lane, Germantown.

This machine may be best described as an ordinary hand-breaker, so adjusted that steam or horse power may be applied to give it motion. By this means the excessive labor and exertion which renders hand breaking of hemp an objectionable occupation is avoided; one skilful workman can take the place of many, and the cultivation of this important staple (heretofore greatly discouraged by the difficulty of procuring hands to prepare the crop for market) will be promoted.

Physics.—Light.—In a paper read before the Royal Institute by Balfour Stewart, March 17, 1865, the prevailing ideas concerning the composition of the sun are fully discussed. It is worthy of note, that nearly all the conclusions now reached on this subject rest, upon the evidence which photography has enabled us to educe and to put on record in a permanent manner. The conclusions are briefly as follows:

1st. The existence of an atmosphere around the sun outside of its luminous envelop or photosphere. This is proved by the fact that photographs of the sun are less intense around the edges than in the middle, which is only to be explained on the supposition that an absorptive atmosphere surrounds the sun, causing more loss of power to the rays from the sides which must pierce it obliquely, and thus pass through a great depth, than to those from the centre which penetrate it by the direct and shortest road possible.

2d. That the "flames" or brilliant protuberances seen around the

edges of the moon in a total eclipse of the sun, belong to the central orb and not to the satellite. This was proved conclusively by a series of photographs taken during the eclipse of 1860 by De la Rue and others. In these the flames are shown in the successive pictures, to have suffered gradual occultation, and to have been gradually exposed in like manner by the moving planet, thus clearly being attached to or connected with the sun, and not in any wise related to the moon. These "flames," supposed to be in fact detached portions of the luminous envelop or extensions of the same into the solar atmosphere above mentioned, were also shown to possess remarkable actenic power, their shapes being more developed and better defined on the photograph than to the eye, and one *invisible* portion producing a distinct image on the sensitive film.

3d. That there are markings of a regular character over the solar disc, called, from their shape, willow leaves, ripples, &c. These are distinctly visible on some photographs by Mr. Nasmyth.

4th. That the spots in the sun are openings in its photosphere through which its relatively dark mass is seen.

This is fully demonstrated by the order in which the spot and its penumbra (the sloping sides of the opening) disappears as the luminary rotates. A series of photographs taken at the Kew observatory exhibit this in a clear manner.

Electricity.—Under this head we desire to draw attention to some plans for modification in the Bunsen battery, which were lately brought under our notice, and the results of certain experiments made in consequence.

In the first place, we here show you an apparatus constructed by T. & J. N. Chester, of New York, and presented by Mr. Fox, of Queen & Co., of this city. It is a medical coil, remarkable in the first place for its small size, but yet more for the peculiar arrangement of its battery. This consists of two little carbon cups one inch and a half in depth and the same in diameter, containing each a zinc cylinder about the size of an average thimble. For exciting liquid, water, containing a few grains of sulphate of mercury, is employed. With this the apparatus will run for several hours, giving a shock as severe as can well be endured. The apparatus is thoroughly efficient, and from its small size (measuring about 6 by $3\frac{1}{2}$ by 2 inches) and its avoidance of acids, fumes, &c., very convenient. In the course of experiments made to test its efficiency, several facts were developed which we think worthy of notice.

Mr. Fox pointed out to us the circumstance that the addition of common salt increased the energy and constancy of this battery. A little reflection showed that in that case the sulphate of mercury and salt must change elements, so as to produce sulphate of soda (glauber-salt) and chloride of mercury (corrosive sublimate). These substances might therefore be substituted for those before mentioned, having the advantage that they can be obtained from any druggist, while the sulphate of mercury, can only be had at certain places, not being an article in general use. It was, moreover, found on experiment that

if a Bunsen cell was employed, in which the carbon element was of a porous character, (such, for example, as the common imported form manufactured by Deleuil,) the mercury salt might be dispensed with, and the battery (charged with a solution of glaubersalt only) would give for several hours a constant current, quite sufficient to operate a medical coil with all the energy desirable. In this case not only is all inconvenience from acids and fumes avoided, but we also get rid of the poisonous and expensive mercury salt, using one harmless and cheap in the extreme, (5 cents per pound.) The necessity of using *porous* carbon, arises from the fact that hydrogen is liberated in the action of the battery, which would collect on the surface of a dense carbon, so directly impairing the efficiency of the couple, or by occasioning a deposit of metallic zinc in its place, (after that substance had been dissolved in the fluid,) attaining the same end quite as effectually. The *porous carbon*, however, absorbs this hydrogen to a wonderful extent under these conditions, as has been proved by Daniell, Grove, and others, and thus keeps the couple in efficient action for some hours. The oxide of zinc formed, is dissolved by the solution of sulphate of soda, which *has* this power when in galvanic connexion, as was shown by Millon in 1645. See his paper, *Comptes Rendus*, T. 21, page 37.

We see, therefore, that a battery thoroughly efficient for medical purposes may be prepared by placing a cylinder of porous gas-coke within one of zinc, (which should come as near as convenient to it without touching,) and immersing both in a solution of glaubersalt. (A battery of this sort was here exhibited.)

We have also to show you another modification of this widely used Bunsen battery, from the same source as the preceding, *i.e.*, Chester & Co., of New York. The change here consists in the substitution of a solution of chromic acid, for the nitric acid usually employed in the above apparatus. This solution is sold under the name of electropoion fluid, and may be prepared by dissolving 5 ozs. of bichromate of potash in half a gallon of water, and adding to this 6 ozs, by measure, of oil of vitriol. In this case, part of the sulphuric acid combines with potash, setting free the chromic acid, which remains in solution.

As hydrogen, is liberated in the working of the battery, it takes oxygen from the chromic acid, forming water, and reducing the chromium to the condition of a sesquioxide, which is then taken up by another part of the sulphuric acid, and we have at last a solution of chrome alum or double sulphate of chromium and potassium.

We have found by experiment that this fluid works well in a battery which is not called upon for a large and continuous supply of force. Thus with the Ruhmkorff coil, where the contact is being continually made and broken, it gives results little if at all inferior to those obtained with the usual arrangement employing nitric acid. For the electric light, where there is a great resistance interposed, which materially cuts down the quantity, its working is very good; but where a full connexion of the circuit is maintained, as in electro-magnetic experiments, it runs down rapidly while in contact, recovering, however, when the circuit is opened for a few minutes. The reason of this is

obvious. The solution of chromic oxide, formed around the carbon by the action of the battery, is not decidedly different in density from the rest of the liquid; it is therefore sluggish in giving place to fresh liquid which is required to continue the action. Time must therefore be given for this circulation, or if this is denied, the force will rapidly decrease by the accumulation of this inactive material where an energetic one is demanded. For this reason it is that "carbons" of a porous character and large surface are desirable in this battery, the French giving better results than the harder (and otherwise much more desirable ones) manufactured in this country. For the same reason this solution will not act well in a Grove's battery, unless some mechanical means is employed to keep it in constant circulation. Such a battery, stirred by blowing air into it, was introduced some time since in France, but on the large scale cannot be conveniently applied.

Chemistry.—A new process for plating glass mirrors has lately been introduced by a M. Dode. Neutral chloride of platinum is dissolved in water, and oil of lavender is added, by which the platinum is separated in a state of fine division. Litharge and borate of lead are then added, and the mixture is painted over the surface of the glass, which is then heated to redness in an appropriate furnace. If this plan is practically successful, it would afford a material capable of useful applications in some optical instruments, where the double reflection incident to a glass plate "silvered" at the back is injurious; such, for example, as the kaleidoscope for the magic lantern, in which, otherwise, mirrors of the expensive and troublesome speculum metal must be employed.

M. de Chaubry presented to the Academy of Sciences, March 27, a note, describing a new solvent for aniline colors. This is simply a decoction of common soap-bark, (*quilläia saponaria,*) or the Egyptian soap-root, (*Gypsophila strutium.*) Among the advantages of this menstruum enumerated is the equality in tone obtained with mixed colors, which, in the ordinary solutions of mingled alcohol and water, changes as the proportions of these ingredients change, through the evaporation necessarily attending their treatment in use.

A paper on the utilization of brine from salted meat by application of dyalisis was read before the London Chemical Society by William Marcet, M.D., and will be found in the journal of that institution, Dec., 1864, page 405. From experiments made by this author it appears that the material obtained by the above means is very poor in nutritious matter, wanting the crystalloid constituents of flesh, such as phosphates, lactates, kreatine, and kreatinine. This fact should be remembered in connexion with the statements contained in papers quoted in this *Journal*, vol. xlviii, pages 22 and 143.

A new material is manufactured under the name of Linoleum, which is stated to possess many of the valuable qualities of india rubber. It is prepared by oxydizing linseed oil and then combining it with resins, &c. It is said to admit of vulcanizing.

An excellent and cheap ink may be prepared by any one after the following recipe:

Dissolve in about 4 gallons of hot water 3 ozs. of solid extract of logwood; to this add ½ oz. of bi-chromate of potash, dissolved likewise in a little hot water. As soon as the liquids are mingled they assume an intense purplish-blue color, and the ink thus prepared may be used at once. It acquires a black color on the paper while drying. It does not corrode steel pens. It does not fade, as we know by personal experienae during six years, for which time we have used it exclusively. The cost of materials is about 3 cents per gallon. It is often used to mark packages and boxes. Specimens of writing with this ink, six years old, were here exhibited, and bottles filled with it were presented to all the members present.

Metallurgy.—An improvement in the character of the product is said to result from the introduction of sulphate of iron and oxide of lead, in the ordinary iron puddling furnace. (*Mechanic's Magazine*, April 1865, page 216.)

The Academy of Sciences at Brussels have awarded a gold medal to M. Caron for an essay on steel. In the course of this paper occurs this statement: "Iron in becoming steel does not absorb nitrogen."

In our own *Journal* last year, vol. xlviii, page 283, will be found a very full description of a new form of iron furnace, known as the Rachette furnace. In the German *Miners' and Metallurgists' Journal*, published at Berlin, we find some account of one of these furnaces erected at Mülheim, from which great results were expected in the direction of economy of fuel and amount of product. As this is a matter of great practical interest, we insert here a translation of the article above mentioned, kindly prepared by R. H. Lamborn, Secretary of the American Iron and Steel Association.

Translated from the Berg und Huettenmaennische Zeitung, for Jan. 8, 1865.—Of the various advantages that have been hoped for from the Rachette furnace, viz: lower first cost, high daily production, and economy of fuel, only the first mentioned has been realized at the works at Mühlheim. The furnace cost only one-half to two-thirds as much as a common blast furnace. While many coke furnaces produce 60,000 lbs. of iron per 24 hours, the Rachette furnace produced only 30,000 to 35,000 lbs. of white cast iron in the same period. At Concordia furnace 0·37 lb. of coke is necessary to smelt 1 lb. of charge; at Mühlofen, 0·34 lb. of steel 0·28 lb., while the Rachette furnace requires 0·42 lb. coke to do the same work.

Without doubt the Rachette furnaces present eminent advantages in possessing a large hearth and an excellent distribution of the blast, but the common furnaces have made great advances towards excellence by widening their hearths and increasing the quantity of air thrown in.

Mr. Nystrom then presented several papers by Messrs. Antony Pamfilli and C. Latimer, which were referred to the Committee on Publications.

In reporting the proceedings of the Institute at the stated meeting, April 20, an error was made in describing the alloy prepared by the U. S. Composition Iron Co., New York. It is there stated to consist of zinc, *lead*, and tin, while it is in fact composed of zinc, *copper*, and tin.

HENRY MORTON, *Secretary.*

A Comparison of some of the Meteorological Phenomena of JUNE, 1865, *with those of* JUNE, 1864, *and of the same month for* FOURTEEN *years, at Philadelphia, Pa.*, Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	June, 1865.	June, 1864.	June, for 14 years.
Thermometer—Highest—degree, . .	93·00°	96·00°	98·00°
" date, . . .	30th.	26th.	29th, 1856.
Warmest day—mean,	85·33	89·67	90·50
" " date,	30th.	26th.	30th, 1856.
Lowest—degree, . .	61·00	51·00	42·00
" date, . . .	6th.	12th.	5th, 1859.
Coldest day—mean, .	65·33	59·33	55·00
" " date, .	6th.	11th.	6th, 1861.
Mean daily oscillation,	13·23	17·42	16·20
" " range, .	4·52	5·69	4·84
Means at 7 A. M., . .	73·79	67·33	68·86
" 2 P. M., . .	83·28	78·23	78·85
" 9 P. M., . .	74·73	70·03	71·34
" for the month,	77·26	71·86	73·02
Barometer—Highest—inches, . . .	30·069 ins.	30·087 ins.	30·281 ins.
" date, ...	6th.	21st.	13th, 1852.
Greatest mean daily press.,	30·056	30·028	30·251
" date, ...	6th.	21st.	13th, 1852.
Lowest—inches, . . .	29·589	29·296	29·183
" date, ...	26th.	9th.	11th, 1857.
Least mean daily press., .	29·664	29·358	29·262
" date, . . .	26th.	9th.	11th, 1857.
Mean daily range, . . .	0·081	0·127	0·099
Means at 7 A. M., . . .	29·854	29·812	29·811
" 2 P. M., . . .	29·821	29·777	29·777
" 9 P. M., . . .	29·841	29·805	29·792
" for the month, .	29·839	29·798	29·793
Force of Vapor—Greatest—inches, .	0·848 in.	0·850 in.	1·059 in.
" date, . .	30th.	25th.	30th, 1855.
Least—inches, . .	·325	·221	0·162
" date, . . .	15th.	28th.	5th, 1859.
Means at 7 A. M., .	·625	·454	·514
" 2 P. M., .	·664	·475	·536
" 9 P. M., .	·646	·503	·549
" for the month,	·645	·477	·533
Relative Humidity—Greatest—per ct.,	90·0 per ct.	89·0 per ct.	100·0 per ct.
" date, .	9th.	5th.	6th, 1856.
Least—per ct., .	39·0	24·0	22·0
" date, . .	15th.	28th.	16th, 1863.
Means at 7 A. M.,	74·1	65·9	72·1
" 2 P. M.,	57·9	48·4	53·9
" 9 P. M.,	74·2	67·1	70·3
" for the month,	68·7	60·4	65·4
Clouds—Number of clear days,* . .	8	10	8·1
" cloudy days, . .	22	20	21·9
Means of sky cov'd at 7 A. M.,	63·7 per ct.	48·7 per ct.	59·0 per ct.
" " " 2 P. M.,	65·0	54·7	60·8
" " " 9 P. M.,	43·0	46·0	44·4
" " for the month,	57·2	49·8	54·7
Rain—Amount, ...	4·815 ins.	2·246 ins.	4·388 ins.
No. of days on which rain fell, . . .	11	7	11·6
Prevailing Winds—Times in 1000,	s30° 39′ w·188	s73°30′w·343	s74°22′w·222

* Sky, one-third or less covered at the hours of observation.

JOURNAL

OF

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OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

AUGUST, 1865.

CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

Minimum Material in a Trussed Girder. (*A Thesis.*) By WILLIAM BOUTON, (University of Michigan.)

I propose to find the inclination of the braces (*or ties*), *and the relation between the length and depth of a truss with horizontal chords, so as to demand the least amount of material in the construction, when the transverse section of the several parts are made proportional to the strains to which they are subjected.*

An exact analytical solution, I consider, from the nature of the case, impossible; but I desire to make an exact solution upon the following hypotheses, which may be more or less nearly realized in practice:

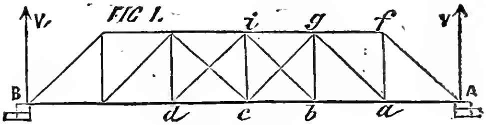
1st. Assume that the weight of the bridge is a uniform permanent load.

2d. Consider the surcharge—or moving load—as uniform as far as it extends.

3d. Assume that the joints at the ends of the braces or ties are perfectly flexible.

These assumed, and I can use the formulas which have been developed in the course of lectures on constructions, and which have been reproduced in this *Journal* by Professor Wood in his articles on "The General Problem of Trussed Girders," to which I shall hereafter refer. I will first consider the panel system, in which the inclined pieces are braces, and the vertical ones ties; in other words, I will consider a Howe's truss,—letting the load be on the lower chord.

FIG. 1.



Notation.

Let $L = A\,B =$ the span,

$D = a\,f =$ the depth,

$l = A\,a = a\,b = b\,c =$ the length of each bay,

$N =$ number of bays, $\therefore\ l = L \div N$,

$W_1 =$ the weight of the frame,

$w_1 = W_1 \div N =$ the weight of one panel,

$p =$ the weight of the surcharge on one panel,

$r =$ the weight of the surcharge per foot of length,

$$c = \frac{w_1}{p}, \text{ and } w_1 = \frac{crL}{N}, p = \frac{rL}{N},$$

$$\therefore p + w_1 = (1 + c)\frac{rL}{N}, \quad . \quad . \quad (1.)$$

$W =$ the total load $= (p + w_1)\,N$,

$\theta = g\,a\,f$ the inclination of a brace.

We have

$$D = \frac{l}{\tan\theta} = \frac{L}{N\tan\theta}, \quad . \quad . \quad (2.)$$

The length of a brace $= D \sec\theta = \dfrac{L\sec\theta}{N\tan\theta}$, . . (3.)

We will take up the problem by parts, and suppose, first, that the braces only are varied in size, and that the load is uniform over the whole length.

The strain on the nth brace is, (see the second of equations (45) p. 381, vol. xlviii,) $\frac{1}{2}(N - 2n + 1)(p + w_1)\sec\theta$, . . (4.)

By making $n = \frac{1}{2}N$ in the 3d of the same equations, we find for the strain at the middle of the lower chord,

$$\tfrac{1}{8}\,\frac{N^2 l\,(p + w_1)}{D} = \frac{W\,L}{8D} = \frac{W\,N}{8}, \quad . \quad . \quad (5,)$$

and, by the hypothesis, the chord is to be made large enough throughout to resist this strain.

Making $\sec\theta = 1$ in (4), and we have

$$\tfrac{1}{2}(N - 2n + 1)(p + w_1), \quad . \quad . \quad (6,)$$

for the strain on the nth vertical tie; but as they are to be of uniform size, they must all be as large as the first one, the strain on which is found by making $n = 1$ in (6). Hence the strain is

$$\tfrac{1}{2}(N - 1)(p + w_1), \quad . \quad . \quad (7.)$$

Let $K =$ the section of a brace,

$S =$ the strain on a unit of section.

Hence (4) and (1) give

$$\text{K} = \frac{(\text{N}-2n+1)(1+\text{c})}{\text{S}} \frac{r\,\text{L}}{2\text{N}} \sec\theta, \quad . \quad (8.)$$

In (8) make $n=1, 2, 3$, &c., ... to $\frac{1}{2}\text{N}$, and we shall form a series, the successive terms of which give the sections of the braces in their order. Summing the series, and we have for the total sections of the braces on half the bridge,

$$\Sigma\text{K} = \frac{\text{N}(1+c)\,r\,\text{L}}{8\text{s}} \sec\theta,$$

which, multiplied by the length of a brace, equation (3), gives for the volume of half the braces,

$$\frac{(1+c)\,r\,\text{L}^2}{8\text{s}}, \frac{1}{\cos\theta\,\sin\theta}, \quad . \quad . \quad (9,)$$

which is a minimum, for $\theta = 45°$. Hence, the minimum amount of material in the braces is

$$\frac{(1+c)\,r\,\text{L}^2}{2\text{s}} = \frac{p+w_1}{2\text{s}} = \frac{\text{NL}}{\text{N}} \quad . \quad (10.)$$

This shows that the total amount of material in the braces is the same as if the truss were a king-post with braces inclined at an angle of 45 degrees. The aggregate length of the ties will be the same whether the truss be composed of two or many braces; hence, equation (7) shows that the amount of material in the truss is least when N is least, or equal 2; hence the king-post truss requires *less* material for the ties and braces. Equation (5) shows that the strain on the chord varies with N; hence, the section of the chord is least in the king-post truss. When the inclination of the braces is varied, we shall still find an advantage in the king-post truss, but not as great as in the present case.

Next, *suppose that both the ties and braces are proportioned according to the strains to which they are subjected*, the load being uniform throughout.

By summing the series found by equation (6), and multiplying by the length of a tie, equation (2), we find for the volume of half the ties,

$$\frac{(1+c)\,r\,\text{L}^2}{8\text{s}}, \frac{1}{\tan\theta} \quad . \quad . \quad (11.)$$

Twice the sum of (9) and (11) gives the total volume of the ties and braces, which is

$$\frac{(1+c)\,r\,\text{L}^2}{4\text{s}} \left(\frac{1}{\cos\theta\,\sin\theta} + \frac{1}{\tan\theta} \right) \quad . \quad (12,)$$

which is a minimum for $\theta = 54°\ 45'$.

In the following table, the second column shows the relative amount of material in the braces only, for different inclinations; and the fourth column shows the relative amount in both ties and braces:

θ	$\frac{1}{\cos\theta\sin\theta}$	θ	$\frac{1}{\cos\theta\sin\theta}+\frac{1}{\tan\theta}$
45°	100·00	54° 45′	100·
40° or 50°	101·50	50°	101·5
35° or 55°	106·40	45°	106·4
30° or 60°	115·50	40°	113·7
25° or 65°	130·55	35°	125·7
20° or 70°	195·85	30°	142·9
15° or 75°	200·00	25°	168·1
10° or 80°	368·09	20°	207·1
5° or 85°	515·00	10°	407·3
0° or 90°	∞		
		60°	102·1
		65°	108·8

If we make the strains those due to a moving load, the braces (in the form of counter braces) will pass beyond the centre, and the *coefficient* of $\frac{1}{\tan\theta}$ will be less than that of $\frac{1}{\cos\theta\sin\theta}$; hence, will reduce the value of θ for the function a minimum toward 45°, a limit it can never reach. Indeed, it cannot reach 48°; for using the first two terms of equation (20) and make $w_1 = 0$, and $n_1 = N - 1$, and solve for a minimum, and we find

$$(N^2 - 1)\tan^2\theta = \frac{31}{24}N^2 - \frac{28}{24}.$$

If N be very large, we have approximately

$$\tan^2\theta = \frac{31}{24} \therefore \theta = 48^\circ\ 40',$$

which is the limiting value, but the practical value is nearer 54°.

General Problem.

The amount of material in the chords diminishes as the depth of the truss increases—N and L being constant—but this diminishes θ, hence increases the material in the ties and braces when θ is less than 54° 45′. Hence, there must be some value of θ which will give the amount of material required for *all* the parts a minimum.

When the load is uniform throughout and permanent, we know that no counter braces are necessary, and that all the braces incline towards the centre. But the surcharge which moves on or off is uniform over only a portion of the length, and the most unfavorable case is when it extends from one end of the bridge to the point considered. This case necessitates counter-braces. To find the number of braces which, in this case, must incline from either end, we place the second of (46) page 381, vol. xlviii, equal zero and solve for n. Call the rational value n_0, and we have

$$n_0 = N\frac{w}{p} + N + \tfrac{1}{2} - \sqrt{N^2\left(\frac{w^2}{p^2} + \frac{w}{p}\right) + \tfrac{1}{4}}, \quad . \qquad (13.)$$

Then will the *number* of braces required be the integer part of n_0; or, if n_0 is an integer, it will be n_0-1. Call it n_{ι}.

From the second of (46) above referred to, we have for the section of the nth brace,

$$\text{K} = \Big[(\text{N}-n)\,(\text{N}-n+1)p + (\text{N}-2n+1)\,\text{N}\,w_{\iota}\Big]\frac{\sec\theta}{2\,\text{S}\,\text{N}},$$

which, multiplied by the length, equation (3), gives for the volume of the nth brace,

$$\Big[(\text{N}-n)\,(\text{N}-n+1)\,p + (\text{N}-2n+1)\,\text{N}\,w_{\iota}\Big]\frac{\text{L}}{2\text{S}\,\text{N}^2\sin\theta\cos\theta} \quad (14.)$$

To find the volume of half the braces, form a series by making $\text{N}=1$, 2, 3, &c., to n_{ι}, and sum the series. Two series will be formed, one the coefficients of p; the other of w_{ι}.

1. The coefficient of p.

By the method of the orders of differences, the sum of the series,

$$\text{S} = n\,a + \frac{n\,(n-1)}{2}d_1 + \frac{n\,(n-1)\,(n-2)}{2\cdot3}d_2 + \&\text{c.},$$

in which $n=$ the number of terms,

$a=$ the first term,

d_{ι}, d_2, &c., $=$ the first terms of the several orders of differences.

The terms of the series are

	$\text{N}\,(\text{N}-1)$,	$(\text{N}-1)$, $(\text{N}-2)$,		$(\text{N}-2)$, $(\text{N}-3)$,		$(\text{N}-3)$, $(\text{N}-4)$.	
1st dif.	$-2\text{N}+2$		$-2\text{N}+4$		$-2n+6$.		
2d dif.		$+2$		$+2$		$+2$.	
3d dif.			0		0.		

Substituting in the formula, and we have

$$\Big[n_{\iota}\,\text{N}\,(\text{N}-n_{\iota}) + \tfrac{1}{3}\,n_{\iota}\,(n_{\iota}^2-1\Big]\text{ to be multiplied by }\frac{p\,\text{L}}{2\text{S}\,\text{N}^2\sin\theta\cos\theta}.$$

2. Coefficient of w_{ι}.

This becomes negative when we pass the centre, and each term cancels a corresponding one before we arrive at the centre; hence we need sum only from $n=1$ to $n=\text{N}-n_{\iota}$.

The terms of these series are

	$\text{N}\,(\text{N}-1)$		$\text{N}\,(\text{N}-3)$		$\text{N}\,(\text{N}-5)$		$\text{N}\,(\text{N}-7)$.
1st dif.		-2N		-2N		-2N.	
2d dif.			0		0,		

and the sum for $(\text{N}-n_{\iota})$ terms is

$$n_{\iota}\,\text{N}\,(\text{N}-n_{\iota})\text{ which is to be multiplied by }\frac{\text{N}\,w_{\iota}\,\text{L}}{2\text{S}\,\text{N}^2\sin\theta\cos\theta}.$$

Adding the results, and using equation (1), and we have for *the total volume in half the braces*,

$$\Big[\text{N}\,n_{\iota}\,(\text{N}-n_{\iota})\,(1+c) + \tfrac{1}{3}\,n_{\iota}\,(n_{\iota}^2-1)\Big]\frac{r\,\text{L}^2}{2\text{S}\,\text{N}^3}\,\frac{1}{\sin\theta\cos\theta} \quad (15.)$$

Material in the Vertical Bars.

The equation for the strain is the same as for the braces, except that $\sec\theta = 1$. The length is $\frac{L}{N\tan\theta}$. It will make a difference, whether N be odd or even. If N be odd, there will be $\frac{1}{2}(N-1)$ ties in half the bridge; and hence, $\frac{1}{2}(N-1)$ terms in the series. Hence the volume is

$$\left[\tfrac{1}{4}N(N^2-1)(1+c)+\tfrac{1}{6}(N-1)\left(\tfrac{1}{4}(N-1)^2-1\right)\right]\frac{rL^2}{2sN^3},\frac{1}{\tan\theta}.\text{*}\quad(16.)$$

If N be even, there will be a middle tie, and after summing the series for $n_1 = \frac{1}{2}N$ terms, we must deduct one-half the volume of the middle tie. The volume of the middle tie is found by making $n = \frac{1}{2}N$, and $\sec\theta = 1$ in the first term of (14), and using $\tan\theta$ for $\frac{1}{\sin}\theta$. Hence the half volume is

$$\tfrac{1}{8}N(N+2)\frac{rL^2}{2sN^3}\frac{1}{\tan\theta}.$$

Summing $\frac{1}{2}N$ terms of the series, and deducting the preceding expression, and we have for the volume of one-half the ties,

$$\left[\tfrac{1}{4}N^3(1+c)+\tfrac{1}{6}N\left(\tfrac{1}{4}N^2-1\right)-\tfrac{1}{8}N(N+2)\right]\frac{rL^2}{2sN},\frac{1}{\tan\theta}\qquad(17.)$$

Material in the Chords.

The equation of the strain is (see the third of (45), page 381, vol. xlviii),

$$\tfrac{1}{2}(N-n)\,n\,(p+w_1)\tan\theta,\qquad(18.)$$

For the half span the limits for n are, when N is even, $n = 1$ to $n = \frac{1}{2}(N-2)$ in the upper chord, and $n = \frac{1}{2}N$ in the lower. If N is odd, the limits are $n = 1$ to $n = \frac{1}{2}(N-1)$ in both chords, by omitting half the central bay in the lower, and including it in the upper chord, since their sections are the same. In either case the summation will be

$$\tfrac{1}{6}N(N^2-1)(1+c)\frac{rL^2}{2sN^2}\qquad(19.)$$

Adding (15), (16), or (17) as the case may be, and (19), and we have for half the volume of the truss,

$$\left\{\begin{array}{l}\left[Nn_1(N-n_1)(1+c)+\tfrac{1}{3}n_1(n_1^2-1)\right]\\ +\left\{\begin{array}{l}(\text{for } n \text{ odd})\ \tfrac{1}{4}N(N^2-1)(1+c)+\tfrac{1}{6}(N-1)\\ (\text{for } n \text{ even})\ \tfrac{1}{4}N^3(1+c)+\tfrac{1}{6}N\left(\tfrac{1}{4}N^2-1\right)\end{array}\right\}\\ +\ \tfrac{1}{6}N^2(N^2-1)(1+c)\tan\theta\end{array}\right\}$$

$$\left\{\begin{array}{l}\dfrac{1}{\cos\theta\sin\theta}\cdot\\ \left.\begin{array}{l}\left(\tfrac{1}{4}(N-1)^2-1\right)\\ -\tfrac{1}{8}N(N+2)(1+c)\end{array}\right\}\dfrac{1}{\tan\theta}\end{array}\right\}\frac{rL^2}{2sN^3}\qquad(20.)$$

* We have made no distinction between the resistance to tension and compression.

which is to be a minimum.

$$\therefore \left\{ \begin{array}{l} \left[\mathrm{N}\, n_{\iota}(\mathrm{N}-n_{\iota})(1+c) + \frac{1}{3} n_{\iota}(n_{\iota}^{2}-1) \right] \\ -\left\{ \begin{array}{l} (n \text{ odd})\ \frac{1}{4}\mathrm{N}(\mathrm{N}^2-1)(1+c) + \frac{1}{6}(\mathrm{N}-1) \\ (n \text{ even})\ \frac{1}{4}\mathrm{N}^3(1+c) + \frac{1}{6}\mathrm{N}(\frac{1}{4}\mathrm{N}^2-1) \end{array} \right\} \\ \quad + \frac{1}{6}\mathrm{N}^2(\mathrm{N}^2-1)(1+c)\tan^2\theta \end{array} \right\}$$

$$\left\{ \begin{array}{l} (\tan^2\theta - 1) \\ \left\{ \begin{array}{l} \left(\frac{1}{4}(\mathrm{N}-1)^2-1\right) \\ -\frac{1}{8}\mathrm{N}(\mathrm{N}+2)(1+c) \end{array} \right\} \end{array} \right\} = 0, \quad . \quad . \quad (21).$$

We see that the inclination is dependent upon the number of bays. To solve (21) assume N and c, and find n_{ι} by means of (13), and then we may find θ. In this way the following table has been computed.

TABLE *showing the inclination of the braces and the ratio of the length to the depth of a* HOWE'S TRUSS, *for a minimum amount of material, load on the lower chord:*

Value of N.	Uniform and permanent load. $p=0$ and $c=\infty$		$p=w_{\iota}\ \therefore\ c=1$		$p=2w_{\iota}\ \therefore\ c=\frac{1}{2}$			$w=0\ \therefore\ c=0$	
	θ	$\frac{L}{D}$	θ	$\frac{L}{D}$	θ	$\frac{L}{D}$	Rel. value of $\frac{r\,L^2}{S}$ Eq. (20.)	θ	$\frac{L}{D}$
	° ′		° ′		° ′			° ′	
2	40 53	1·73	40 53	1·73	40 53	1·73	100	40 53	1·73
3	39 14	2·45	39 36	2·48	39 43	2·49	135	39 55	2·51
4	35 47	2·88	36 25	2·95	36 35	2·96		37 23	3·05
5	34 12	3·40	34 51	3·48	35 5	3·51		35 39	3·59
6	31 51	3·72	32 29	3·81	32 30	3·82		33 21	3·95
7	30 26	4·11	31 28	4·28	31 46	4·34		32 28	4·45
8	29 1	4·46	29 48	4·58	30 13	4·66	217	31 7	4·82
9	28 7	4·81	28 54	4·97	29 11	5·03		30 0	5·20
10	26 48	5·05	27 41	5·24	27 48	5·27		28 6	5·34
12	25 2	5·60	25 54	5·82	26 13	5·91		27 28	6·23
15	23 5	6·39	23 52	6·64	24 10	6·73		25 0	6·99
20	20 31	7·49	21 21	7·81	21 39	7·93	274	22 32	8·36
25	18 36	8·41	18 41	8·45	18 57	8·58		20 22	9·23
30	17 21	9·37	17 51	9·66	18 8	9·84		18 56	10·30
40	15 23	11·00	15 40	11·22	15 54	13·39		16 41	12·00
50	13 34	12·87	14 7	12·57	14 23	18·52	506	15 3	13·44
60	12 26	13·23						13 49	14·80

For $p = 2w_{\iota}$, I have added a third column of the relative value of the coefficients of $\frac{r\,L^2}{S}$ in equation (20). By this it appears that to support a *moving* surcharge, r L, plus a *uniform permanent* load $\frac{1}{2}r$ L, will require 5·06 times the material when the span is divided into fifty bays that it would if divided into two.

Although we find that the material does not increase with the number of bays so fast as it would if θ remained constant, still the increase is so great as to forbid our increasing N until there is no danger of rupture by flexure in the braces. But N must be increased until there is no danger of breaking in the loaded chord from transverse strain.

Let P be the greatest concentrated load which can come on any bay *e.g.*, on the driving wheels of a locomotive, $\therefore \frac{1}{4}\,\text{P}l = \frac{1}{6}\,\text{R}\,bd^2$, but $bd = \text{K} \therefore \text{K} = \frac{3}{2}\frac{\text{P}l}{\text{R}b}$, which section must be less than that required to satisfy the formula $\frac{1}{2}(\text{N}-n)\,n\,(p + w_1)$ tang $\theta = \text{S K}$. See equation (18.) This may be effected by making l, the length of the bay, small, or making d larger in proportion to b throughout the span. On the whole, I think it would be better to increase the section of the loaded chord so as to prevent danger from transverse strain, and not alter the disposition of the other parts, for such an alteration would increase the material in all the other parts, to avoid a danger which only requires the increase of one part.

Triangular Systems.

When the load is on the upper chord we find from equations (43) and (44), page 379, vol. xlviii, that

$$\left[(\text{N}-n)^2 p + (\text{N}^2 - 2n\text{N})\,w_{\iota}\right]\frac{\sec\theta}{2\,\text{N}} = \text{the maximum strain on the pair}$$

of braces at the end of the nth bay.

$(\text{N}-n)\,n\,(p + w_{\iota})\tan\theta$ = strain on nth bay of upper chord.

$\left[\text{N}\,(n-\tfrac{1}{2}) - (n-1)\,n\right](p + w_{\iota})\tan\theta$ = strain on nth bay of lower chord.

Sum these equations for all integral values of n from the end to the centre of the truss.

1°. For the braces WHEN N IS EVEN and the first bar is a brace,

$n = 0$ to $\frac{1}{2}(\text{N}-2)$ for the main braces,
$n = 1$ to $\frac{1}{2}$ N for the ties.

Expanding the equation for the braces and ties with these limits, and we get for the total section of half the braces and ties when N is even,

$$\Sigma\text{K} = \frac{7\,\text{N}^3 p + 6\,\text{N}^3 w_{\iota} + 2\,\text{N}\,p}{12}\cdot\frac{\sec\theta}{2\,\text{N S}}$$

The length of a brace is $\frac{\text{L}\sec\theta}{2\,\text{N}\tan\theta}$; hence,

Volume of half the braces and ties,

$$= \frac{(7 + 6c)\,N^2 + 12}{4} \cdot \frac{r\,L^2}{12\,N^2\,S} \cdot \frac{1}{\cos\theta \sin\theta}$$

WHEN N IS ODD.

The limits for the main braces are, $n = 0$ and $n = \frac{1}{2}(N-1)$.
for the ties $n = 1$ and $n = \frac{1}{2}(N-1)$.

$$\therefore \text{ the volume} = \frac{(7 + 6c)\,N^2 + 5 + 6c}{4} \cdot \frac{r\,L^2}{12\,N^2 S} \cdot \frac{1}{\cos\theta \sin\theta}$$

The Chords.

For N *even* the limits are $n = 1$ and $n = \frac{1}{2}N$, by subtracting $\frac{1}{2}(N - \frac{1}{2}N)\frac{1}{2}N = \frac{1}{8}N^2$ for half the central bay in the upper chord.

$$\therefore \text{ the volume} = (2\,N^3 + N)(1 + c)\frac{r\,L^2}{2\,N^2 S} \tan\theta.$$

For N *odd*, the limits are $n = 1$ and $n = \frac{1}{2}(N-1)$ for the upper chord, and $n = 1$ and $n = \frac{1}{2}(N + 1)$ for the lower chord, minus half the central bay of the lower chord, viz: $\frac{1}{8}(N + 1)$,

$\therefore$ volume $= (2N^3 + N)(1 + c)\dfrac{r\,L^2}{2S\,N^2} \tan\theta$, the same result as before.

Hence the total material in half the truss is

$$\left[\left\{\begin{matrix} \frac{1}{4}\Big((7 + 6c)\,N^2 + 2\Big)(\text{for N even}) \\ \frac{1}{4}\Big((7 + 6c)\,N^2 + 5 + 6c\Big)\text{for N odd}) \end{matrix}\right\}\frac{1}{\cos\theta\sin\theta} + \right.$$

$$\left.(2\,N^3 + N)(1 + c)\tan\theta\right]\frac{r\,L^2}{12\,S\,N^2}, \quad . \quad . \quad . \qquad (22.)$$

which for a minimum gives

$$\begin{matrix}\text{N even,} \\ \text{N odd,}\end{matrix}\left\{\begin{matrix}(7 + 6c)N + 2 \\ (7 + 6c)\,N^2 + 5 + 6c\end{matrix}\right\}(\tan^2\theta - 1) + (8\,N^3 + 4\,N)(1 + c)$$
$$\tan^2\theta = 0, \quad . \quad . \quad . \qquad (23.)$$

It will be observed that I have considered the compressive and tensive resistances equal; otherwise the final equation would be slightly modified.

From equation (23) and the equation $\dfrac{L}{2\,N\tan\theta} = D$, I have made the following table:

Values of N	Values of c	θ	$\frac{L}{D}$
		° ′	
6	$\frac{1}{2}$	19 11	4·17
9	$\frac{1}{2}$	16 14	5·03
40	$\frac{1}{2}$	8 8	11·43
50	0	7 28	13·11
12	0	14 37	6·25

I have chosen these values of N and c wholly at random; and it will be perceived that the ratio of L to D corresponds very nearly with the results for the panel system for the same value of N.

Approximation.

When N is large we may drop all the terms below N^2, and we shall have

$$(7+6\,c)\,(\tan^2\theta - 1) + 8\,N\,(1+c)\tan^2\theta = 0. \qquad (24.)$$

In this, when $N = 9$ and $c = \frac{1}{2}$, the formula differs from the exact one, less than a minute in the value of θ. For larger values of N the difference will be inappreciable, as shown from the following table:

N=	c=	θ	$\frac{L}{D}$
		° ′	
12	0	14 37	6·25
40	$\frac{1}{2}$	8 8	11·43
50	0	7 28	13·11

This approximation may be made for the panel system to get the relation of L to D, since the relation is nearly the same in both systems. The peculiar value of the factor n_{ι} in the panel system forbade such an approximation in the general equation.

In like manner, we may determine the relation between the length and depth, and the proper inclination of the braces, in any truss in which the strains may be expressed by a continuous function.

The relation of p to w_1 in any practical case cannot be accurately known beforehand, but as all possible inclinations are found from the equation between that resulting when $p = 0$, and that when $w_{\iota} = 0$, and as these values do not differ more than two degrees, a very close approximation may be very readily arrived at. The function varies slowly about its minimum so that a *degree* even will make little difference.

We should diminish the number of bays as much as possible consistently with the liability to rupture by transverse strains and flexure by too great length, and having fixed upon N, determine the relation of p to w_1 as nearly as possible, and then make $\frac{L}{D}$ correspond to the equation for minimum material.

It will be seen that the results which I have obtained for the minimum material, all approximate the value of θ required for the minimum depression of a single triangle composed of bars of uniform section, and sustaining a weight at its apex ; that is, they are nearer it, (30°,) than they would be if inclined so that the material in the ties and braces above should be a minimum. Let me suggest to the patient reader that a triangle sustaining compression in both its braces, is not in the same condition as one sustaining compression in one and extension in the other, as in the case of all bridges. Let me also inquire what effect the compression in the upper chord has upon the rigidity of the whole? Is 30° then an approximation to the inclination for the greatest rigidity in a trussed girder?

Multiple Systems or Lattice Trusses.

In adhering to the simple systems I have shown that the minimum material in the *whole* is obtained by increasing that in the braces above the minimum amount, and so increasing the depth of the truss. Cannot both advantages be combined by retaining the depth of the truss while increasing the inclination of the braces by passing them across two or more panels? This course, while it increases the length of the braces, so much reduces their section as to require less material if we neglect flexure. But both these modifications leave them much more liable to flexure; moreover, the strains cannot be rigidly analyzed, so that much more will have to be added for safety, as well as to prevent the increased liability to flexure, so that we should have little gain. This criticism does not apply to Whipple's truss, or to any other in which the inclined bars are ties. In them I think the multiple system must be advantageous, although it cannot be rigidly calculated.

On Uniform Stress in Girder Work; illustrated by reference to two bridges recently built. By Mr. CALLCOTT REILLY, Assoc. Inst. Civ. Eng.

From Newton's London Journal of Arts, June, 1865.

This communication was suggested by a previous discussion at the Institution, when Mr. Phipps (M. Inst., C.E.,) condemned the trough-shaped section commonly adopted for the top and bottom members of truss girders, because the intensity per square unit of the stress upon any vertical cross section was necessarily variable when the connexion of the vertical web with the trough was made in the usual manner. In the construction of the iron work of the two bridges under consideration, attention was invited chiefly to those details which were de-

signed with the object of carrying out as nearly as possible in every part of the girders the condition of uniform stress.

After alluding to the distinction drawn by Prof. Rankine between the words "strain" and "stress," and to his definition of "uniform stress," in which the "centre of stress" or "centre of pressure" must be coincident with the centre of gravity of the surface of action, and of "uniformly varying stress" when the centre of gravity deviated from the "centre of stress" in a certain known direction, it was remarked that the failure of any member of a girder would begin where the resistance to strain was really the least, that was, where the intensity of the stress was greatest; from which it followed that the opinion which upheld as right in principle the trough-shaped section, as applied in the usual manner, must be a mistake. And, moreover, every form of section of any member of a girder, or other framework, which did not admit of the approximate coincidence of the centre of stress with the centre of gravity, was liable in degree to the same objection.

The two bridges illustrated different conditions of loading; one carrying the platform on the top, the other having the platform between the main girders near the bottom. Both were of wrought iron, and both exhibited an economy of material in the main girders that, so far as the author was aware, was not common at least in this country. In order to determine the causes of this economy, a comparison was made with two other forms of truss more generally adopted. In one bridge over the river Desmochado, on the line of the Central Argentine Railway, the pair of trusses, 93 feet 4 inches span between the centres of bearings, was designed to carry, in addition to the fixed load, a moving railway load of 1 ton per foot of span for a single line of way, with a maximum intensity of stress of 5 tons per square inch of tension, and of $3\frac{1}{2}$ tons per square inch of compression; and the total weight of wrought iron in the framework of the pair of trusses was 18 tons. The cast iron saddles rivetted on at the ends weighed 9 cwt.; if these were included the weight of iron, both wrought and cast, in the pair of trusses was under 4 cwt. per lineal foot of span.

The other bridge, over the Wey and Arun Canal, on the Horsham and Guilford Railway, was 80 feet span between the centres of bearings; it was designed to carry, in addition to the fixed load, a moving load of 1·875 ton per foot of single line of way, at the same maximum intensity of stress as in the other case; and the total weight of wrought iron in the pair of trusses was 20 tons 18 cwt. The cast iron saddles weighed $5\frac{1}{2}$ cwt. each; bringing up the weight of both wrought and cast iron in the pair of trusses to $5\frac{1}{2}$ cwt. per lineal foot of span. This weight was greater than in the first bridge, although the span was less; but the intensity of the moving load was $87\frac{1}{2}$ per cent. greater, and the roadway lying between the trusses instead of on the top, its weight was necessarily much greater. The cross girders were also heavier, each being adapted to support, separately, the heaviest load that could be brought on by a driving axle weighted with 16 tons; the moving load thus brought upon each cross girder, and to which its

strength was proportioned, was 18 tons, equal to $2\frac{1}{4}$ tons per foot of span of bridge.

The particular form of truss chosen for these two bridges was that extensively known in the United States as the Murphy-Whipple truss. Each of these trusses was minutely compared, according to the plan adopted on a previous occasion by Mr. Bramwell (M. Inst. C.E.), with two equivalent trusses of the types generally used in this country, viz: the Warren truss, with bars making an angle of 63° 26′ with the horizon, and the simple diagonal truss with two sets of triangles, the bars crossing each other at the angle of 45°, the various circumstances of ratio of depth to span, which was as 1 to 10, and of application and distribution of load, and consequently the number and position of the loaded joints, being common to the three trusses.

The details of the comparison were fully given in the paper, and the proportionate results arrived at in the two cases were exhibited in the following tables, relating to the trusses of the two bridges contrasted respectively with the other equivalent trusses:

Bridge No. I, with Load on the Top.

	No. 1. Murphy-Whipple Truss.	No. 1 A. Warren Truss.	No. 1 B. Diagonal Truss.
	Units.	Units.	Units.
Theoretical weight, ...	250	237·5	227
Weight of transverse stiffening to struts, ...	17·4	29·2	42·2
Excess of practicable minimum over theoretical minimum, ...	6·18	11·5	31·6
Total weight, exclusive of joints and packings, . .	273·58	278·2	300·8

From this it appeared that the least practicable weight of No. 1 truss was less than that of No. 1 A by only 1·7 per cent. It might, therefore, be said that practically the two trusses were equal in point of economy; and that there could be no motive for preferring one to the other, except such as might arise from considerations of workshop convenience and facility of construction. The advantage in point of economy of weight of No. 1 over No. 1 B was more decided, being 10 per cent.,—sufficient, it was admitted, speaking generally and without denying that special circumstances might in particular cases justify a choice of the heavier truss, to entitle No. 1. to a preference over No. 1 B.

BRIDGE NO II, WITH LOAD ON THE BOTTOM.

	No. 2. Murphy-Whipple Truss.	No. 2 A. Warren Truss.	No. 2 B. Diagonal Truss.
	Units.	Units.	Units.
Theoretical weight, ...	237·8	237·5	228
Weight of transverse stiffening to struts, ...	6·6	16·1	26
Excess of practicable minimum over theoretical minimum, ...	11·98	13·42	32·82
Total weight, exclusive of joints and packings, . .	256·38	267·02	286·82

It thus appeared that No. 2 truss was lighter than either of the others by 4·15 and 11·87 per cent. respectively.

With regard to the peculiarities of detail of the two bridges, it was remarked, that in order that the stress might be uniformly distributed over the surface of any cross section of either "boom," it was necessary that the two halves of the double web of each truss should each support exactly one-half the load upon that truss. This, it was urged, could not be realized by the ordinary modes of fixing the cross girders; but, in the cases under consideration, it was arrived at by supporting the cross girders in the middle of the width of the truss. Thus, in bridge No. I, each cross girder rested upon a light cast iron saddle or bridge, which spanned the width of the top boom, and had its bearing partly upon the top edges of the vertical struts, and partly upon rivets passing through it, the struts, and the vertical side plates of the top boom, in such a way that the line of action of the vertical force transmitted from the cross girder to the truss, coincided exactly with the vertical centre line of its width. In bridge No. II a different arrangement was necessary. In that case each vertical strut consisted of two pairs of angle irons separated in the plane of the truss by a space just wide enough to permit the end of the cross girder to pass in between the pairs. At the same level as the cross girder a plate was riveted to each pair of angle irons; and to the centres of these plates the cross girder was also riveted, so that the weight was equally divided between the four vertical angle irons, and the resulting stress was equally distributed between the two halves of each boom. In both bridges the centre lines of the vertical struts, the diagonal ties, and the top and bottom booms, intersected each other at the centre of gravity of the group of rivets which attached each strut and tie to the boom, and, in order to satisfy the condition of uniform stress, all the centre lines were axes of symmetry. In the top booms of both bridges a section had been adopted which was believed to be new. It was somewhat like an elongated capital letter H, or like a common plate

girder placed upon its side; the horizontal web or diaphragm being only sufficiently thick to ensure lateral stiffness. In this section all the centre lines were axes of symmetry, and consequently intersected each other in its centre of gravity; and the horizontal axes were easily made to intersect the centre of gravity of the web-joints. The chief mass of metal was also placed immediately contiguous to the bars of the web, which transferred the stress to the boom, instead of being at some distance from them, as in the trough-shaped and T-shaped form of boom. The material was likewise disposed in the best possible manner for resisting vibration, while this section gave complete facilities for examination and painting. The ends of each truss rested upon hinged bearings by means of cast iron saddles riveted to the junction of the endmost bars of the truss, rollers being provided at one end.

The means adopted in the designs of these girders to obtain the utmost economy of weight consistent with moderate economy of workmanship were: The closest practicable approximation of the average strength to the minimum strength; the observance throughout of the condition of uniform stress, in order that all the compressed members might be trusted with the least possible weight of stiffening; the preference of riveted web-joints to those formed by single pins, and such an arrangement of the riveting that every bar or plate subject to tension should have its whole width, less the diameter of only one rivet hole, available to resist the tensile force applied to it.

Lastly, the author demonstrated the true value of the condition of uniform stress by an exact comparison of the state of a bar of the top boom of the truss of bridge No. II, when under uniform stress, with that condition of unequally distributed stress that would occur if the boom had a suitable trough-shaped section of equal area, breadth, and depth, and therefore of equal nominal value, the elasticity of the material being assumed as perfect. The first case considered was where the stress was uniform in intensity, and the second in which the stress was unequally distributed. The final result was denoted by the equation $p = p_0 \pm \frac{x \text{L} \text{P}}{\text{I}}$; and applying this formula* to the case of the trough-shaped section of the boom, supposed to be equivalent to the H-shaped section actually used, the following was obtained: The area of section was exactly the same, being 36·17 square inches. The inside depth of the trough, 10 inches, would permit precisely the same disposition of the rivets of the web-joint, so that the centre of pressure was situated at the same perpendicular distance, 5 inches, from the lower

* In this formula, p is the intensity of the stress per unit of area at the distance x from the neutral axis of the stress which intersects the centre of gravity of the section. p_0 is the intensity of the stress considered as uniformly distributed over the surface of section; that is, the total pressure P upon the entire surface of section divided by the area of that surface. L is the perpendicular distance of the centre of pressure from the neutral axis, and I is the moment of inertia of the surface with respect to that axis. x is + or —, according as it is measuree on one side or the other of the neutral axis.—C. R.

edges of the trough, as from the edge of the H-shaped section actually used. The centre of gravity was found to be situated at 8·088 inches perpendicular distance from the lower edge of the trough, and 2·537 inches from the top edge. The magnitude of the total stress upon the section was 125 tons. The uniform intensity of the stress was 3·45 tons per square inch, and the moment of inertia with respect to the axis was 336·892. From these data the greatest stress was found to be 12·717 tons per square inch at the extreme edges or corners of the sides, and the least intensity 0·544 ton per square inch along the extreme bottom of the trough. In this result the effect of flexure was purposely omitted.

In summing up the conclusions sought to be established, it was submitted that—

First, a comparatively small deviation of the centre of the stress, upon the cross section of any bar of any piece of frame-work from the centre of gravity of that section, produced within the limits of elasticity a very great inequality in the distribution of the stress upon that section.

Secondly, if it were conceded that the real strength of every structure was inversely proportional to the greatest strain suffered by its weakest member, then the existence of this unequal distribution of the stress must be detrimental to the strength of any structure in which it existed, and which had been designed upon the supposition that the mean intensity of the stress upon any bar was necessarily a correct measure of its strength.

Thirdly, there was no practical or theoretical difficulty in designing a truss or girder in which the stress upon every cross section, of all the important members at all events, should be absolutely uniform.

Fourthly, the condition of uniform stress was perfectly consistent with the utmost economy of material in the structure to which it was applied.

On a new Method of Working Atmospheric Railways.—By Francis Campin, C.E.

From the London Artizan, Feb., 1865.

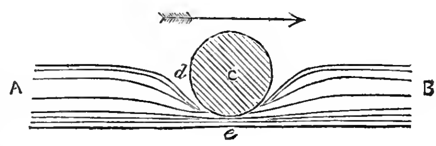
The atmospheric system of railway propulson having been, in several localities, tested as to its practicability and found wanting, appears for some years to have been set aside, no attention being paid to it except by those personally interested in its success; and so the locomotive has had a clear field, having no rival except in one or two instances where the gradients are too heavy for the ordinary mode of working, and stationary power is requisite. Recently, however, the subject of atmospheric propulsion has received attention, as it seems suitable, if its peculiar difficulties can be overcome, for the working of underground railways where the presence of the locomotive is frequently inconvenient. The obvious advantages of a perfect system of atmospheric propulsion are briefly, simplicity of machinery, impossibility

of collision, as two trains cannot meet on one line of rails, nor can one overtake that preceding it; and reducing the weight of the train by displacing the locomotive, and the consequent reduction of wear and tear in the permanent way. The difficulties which have hitherto resisted the practical application of the system are, the mode adopted for connecting the propelling piston to the train of carriages; the continuous valve on the air-tube working very unsatisfactorily; the low pressure at which the propelling power is worked, by the reason that only the atmospheric pressure is available, because if compressed air were admitted within the air-tube, the valve would be blown open and the operation of the machinery stopped; and a valve could scarcely be made to open inwards, as, in that case, it would come in the way of the piston within the tube.

By the method which it is the object of the present paper to describe, any reasonable pressure may be employed, and the difficulty of the valve is obviated by doing away with it entirely. It is the invention of Mr. William Lake, C.E., who has devoted considerable attention to this subject, which is now promising fruitful results to those who shall succeed in practically establishing the utility of the atmospheric railway.

I will now proceed to explain the details of the machinery by means of which it is proposed to conduct the traffic according to Mr. Lake's principle, commencing with the tube and gearing on the carriages.

The air-tube laid between the rails, instead of being rigid, as heretofore, is made of some flexible substance, such as india rubber, upon which runs a roller attached to the bottom of the carriage or carriages to be propelled, the roller also being coated with an elastic substance, and fixed at such a level that it will, by pressing on the tube, collapse and close it at the point of contact. Then, if air be forced into the tube, the roller will be forced along, drawing the train with it, the effect upon the roller being the same as if it were placed upon an inclined plane. The annexed sketch may, perhaps, make the action above described more clear. Let A B represent a portion of the elastic air-tube, compressed so as to be closed by the roller C. If air be forced into the tube at A, then, by reason of the pressure exerted at the point *d*, or rather along the inclined surface *d* of the tube, the roller C is caused to progress along the tube in the direction of the arrow, or from A to B, and *vice versa*. The impelling force will be proportional to the area of the tube A B, and the pressure of the air forced into it, but care must be taken that the diameter of the roller C is properly proportioned to that of the tube A B, or a point may be arrived at where motion will cease, if the roller be continually reduced in size—the larger it is the easier will it work, as the propelling power will have, as it were, a greater amount of leverage; this leverage being proportional to the distance from the centre of force *d*, acting on the roller to the bottom point *e* of the roller.



The first question to be answered as to the practical working of this project on a large scale, is: Will the elastic tubing bear the pressure thrown upon it, and the constant passing of the roller over it? To which it is answered, that not only is it possible to make elastic tubing to fulfil these conditions, but responsible manufacturers are prepared to undertake it, and to guarantee it to a much higher pressure than would ever be required in working, or, in figures, to upwards of 250 lbs. per square inch. Let us now take a case, and determine the size of tube necessary to propel a train at average velocities upon an incline of 1 in 100 rise; the weight of the train will be taken as 50 tons, the speed about 30 miles per hour, and the working effective pressure of the compressed air in the elastic tube 50 lbs. per square inch. In order to be on the safe side, the resistance of the train in rolling friction will be assumed as 20 lbs. per ton.

The resistance from friction will be 50 tons × 20 lbs. = 1000 lbs.; that due to the incline, 50 tons × 2240 lbs. ÷ 100 (ratio of gradient) = 1120 lbs.; total, 1000 lbs. + 1120 lbs. = 2120 lbs. propelling force required; this, divided by the working pressure, gives the area of the working tube. Thus, 2120 lbs. ÷ 50 lbs. = 42·4 square inches, corresponding to a diameter of 7·375 inches. This size is so moderate that it is evident there is no difficulty about getting the requisite power to propel trains upon any incline—(thus, if the gradient were even 1 in 30, the tube would only need an increase of diameter of from 7·375 inches to 11 inches; and it may here be noted that the roller will be, within certain limits, capable of acting on tubes of varying diameters). Now, let us determine the amount of power requisite to maintain the motion of the train at 30 miles per hour on the gradient of 1 in 100. The propelling force is 2120 lbs., and 30 miles per hour equals 2640 feet per minute, giving for the work per minute 2640 feet × 2120 lbs. = 5,596,800 foot lbs., requiring for its performance 169·6 horse-power. To run the same train on a level, the work would be 2640 feet × 1000 lbs. = 2,640,000 foot lbs. corresponding to 80 horse power.

We will now pass on to the means to be adopted for supplying the air at the required pressure to the elastic air-tube. Stationary engines placed at certain points on the line would be employed to force air, not at once into the air-tubes, but into an accumulator, which would at the same time act as a governor. This accumulator would consist of a cylinder with a loaded piston, on which the weight would be such as should equal the pressure to be created in the air-tube; then, if the pumping engine worked too fast, the piston in the accumulator in rising would close the throttle valve, and *vice versa*. In the case of the train leaving one section of tube for another, which would occur at each pumping station, the following course would be adopted to prevent inconvenience arising from the sudden removal of the load from the engine at the previous station:

The train, in passing the end of the section of tube upon which it has been traveling, is caused to act upon a tumbler attached to the permanent way, which tumbler closes the valve admitting air from the accumulator into the elastic air-tube; then the engine pumps air into

the accumulator only, until the plunger therein, by rising, cuts off the steam, and so stops the engine. The same result may be produced in other ways, but the above appears most certain, and, therefore, preferable.

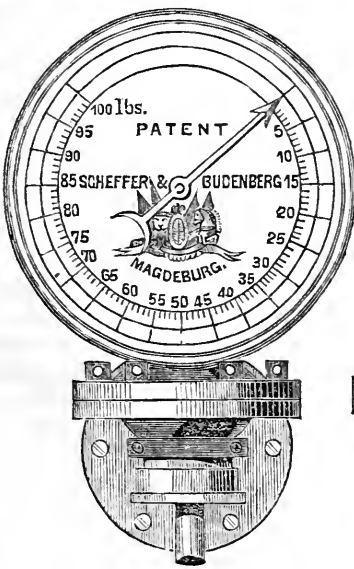
In applying the foregoing method to the propulsion of railway carriages, it is argued that great advantages will be obtained; for the tube is small in size, very durable, and easily replaced; and, further, a uniform speed can be maintained, as the tubes can be increased in size on gradients, the same roller being capable of acting upon tubes of various diameter, as mentioned above, and, by these means, the speed of the train is maintained without raising the pressure in the elastic tube.

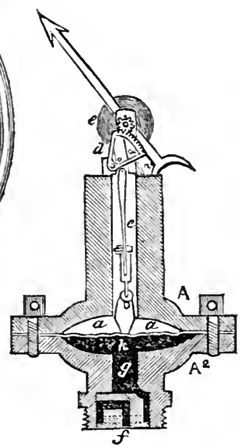
Pressure Gauges and other Instruments used in Steam Engineering.

By Mr. A. Budenberg.

From the London Artizan, February, 1865.

Letters patent was granted to Mr. Schaeffer early in 1850, by the Prussian government, for the invention of the "Manometer," or Pressure and Vacuum Gauge, which I am about to describe to you, and which has become so great a success, as may be judged by the





fact that, since the 23d of January, 1850, when those letters patent were granted, upwards of 60,000 gauges of that construction have been sold. The well known difficulty to obtain letters patent from the government of Prussia, which is particularly illustrated by the refusal of such for Giffard's Injector, gives some reason to believe

that Schaeffer's invention was entirely new and without precedent, when it is remembered that in Prussia the decisions arrived at in applications for letters patent depend entirely upon this point—whether the presumed invention is entirely new, or whether anything similar to it has been made before.

The following is the description of these gauges, whose construction, however, is so simple, that it explains itself fully by reference to the illustration. Their action is direct. The steam or other fluid which is brought by a tube from the boiler or other vessel, exerts its pressure on a corrugated steel plate, *a a*, which is protected from corrosion by a sheet of pure silver, *k*. The plate is thus deflected upwards, and when the pressure is removed, it returns to its original position. It will thus be perceived that the accuracy of the gauge depends almost entirely upon the perfect elasticity of this steel plate. A small block, provided with a socket-joint, is fixed to the joint, and its motion is transferred to the quadrant, *d*, by means of the connecting pieces, *b* and *c*. This quadrant communicates the motion finally to the index by gearing into a small pinion fixed upon the axle or pivot which carries the index, and the gearing is so proportioned as to multiply that motion sufficiently to render the divisions of the dial clear and legible.

The spiral or hair spring, *e*, regulates the motion of the index, and makes it continuous and steady. The dial shows actual pressures, and is accurately divided to the scale of an open mercurial column, and every gauge is repeatedly tested before delivery. The divisions on the dial are in one pound per square inch, and in atmospheres; sometimes they are made to represent the pressure of a column of water, 34 feet, nearly corresponding with one atmosphere, or fifteen pounds pressure per square inch.

For about two years past our firm have manufactured gauges for hydraulic pressure up to ten tons per square inch, on a principle similar to Bourdon's gauge, improved and modified to suit that particular purpose. These gauges, of which a sample is exhibited, are made of a semicircular steel tube, elliptic in its cross section, into which water (or, in preference, oil) is introduced, which, when it is subject to pressure, tends to straighten or uncoil the tube. A toothed connecting rod is attached to the end of the latter, and made to gear into a small pinion fixed upon the spindle to the index, which registers the pressures as divided upon the dial by actual experiment, as is the case with the steam gauges just described, in tons per inch.

Messrs. Brockhurst and Sullivan, of the firm of Dewrance and Co., formerly Bourdon's agents in this country, took a patent in January last for a pressure gauge similar to the one I have just explained, in so far as regards the semicircular tube. These gentlemen claim that particular construction, and the practice of filling the tube with oil, as some of the principal points of their patent, although our firm had adopted that form of tube a considerable time before them, and have tested in Magdeburg and Manchester the tubes and other springs by the medium of oil, a practice which has been adopted by others as

well as ourselves, long before Messrs. Dewrance and Co. thought it worth their while to take a patent for it.

The only point in Messrs. Dewrance and Co.'s patent, which is as original as it is novel, is the introduction of a valve, whose special function is to close up the aperture which connects the tube with the pressure pipe, and thereby to disconnect the whole mechanism of the gauge from that pipe, the pressure of whose contents it is intended to register. The consequence of this arrangement is, that the gauge will register a certain maximum pressure, but it never indicates any excess of pressure, in case such has been attained; whereas it has been our uniform and careful practice to construct our gauges in such manner that the index shall be thrown out of gear, whenever the maximum pressure which the gauge is intended to register has been exceeded; and I shall leave this meeting to judge of the relative merits of Messrs. Dewrance and Co.'s innovation and of our own practice.

Mr. Birckel said: It was my desire to bring this subject before the Society, because I had noticed that shortly after the lapse of the patent of Bourdon's gauge, which had acquired a certain amount of celebrity, the agents of Bourdon in this country took out a patent for certain alleged improvements in these gauges. I did not then know what these improvements were; but having mentioned the circumstance to Mr. Budenberg, he explained to me their nature, when I found that the only novelty was the valve which is intended to shut off the pressure when it has reached a certain density. I thought that a practice like *that* was so contrary to all we had hitherto done in steam engineering, so contrary to all regulations which had hitherto been issued by the Manchester and other Boiler Associations, the tendencies of which have invariably been to render everything accessible, and to divulge everything that is going on in the boiler, that it ought to receive due publicity. Now, here we have a gauge which, for the sake of its own protection, shuts off the pressure, so as to prevent injury to itself from over pressure, although when that point has been reached any amount of extra pressure might be put on the boiler without any one knowing anything about it. As soon as I saw that, I thought it a subject worth bringing before such a Society as this, in order that its merits or rather its demerits, might be made known to the world. Mr. Budenburg labors under the disadvantage of being a foreigner, and cannot explain himself so clearly as we might wish him to do; but he has endeavored to show you that by them a gauge has been constructed, such that, when the maximum pressure has been reached which the gauge is desired to register, the index shall be thrown out of gear; and when that has taken place, it never again can indicate any pressure whatever, until the maker of the instrument, or any person able to do it, has taken it down and put it into working order again. It registers, therefore, the fact that there has been too great a pressure in the boiler (or other vessel)—it registers that fact, and in so far provides a precautionary measure against accidents from over pressure. The merits of Messrs. Budenberg's gauges may be appreciated

sufficiently by the fact that 60,000 of them have been manufactured and used in the space of fourteen years. It appears, from an inspection of its structure, that the principal element in the gauge is the corrugated steel plate, which really forms the spring, by the deflection of which the amount of pressure is indicated; and I think that the correctness of those indications for any continued length of time entirely depends upon the tempering of that steel plate, and upon the quality of the steel of which it is made. I should think that Mr. Budenberg ought to have a few facts to mention in reference to this, namely, how long any of these plates have been known to work with accuracy, and I shall be very glad to be informed of the length of time their elasticity is likely to remain perfect.

Mr. Budenberg.—I may say that in Manchester and in its neighborhood, where great attention has been paid to the working of steam gauges, ours have given the utmost satisfaction. For instance, the Messrs. Hick, of Bolton, who have been using them ever since we have had them in England, declare that they are the best of all gauges. Last year, at Messrs. Hawthorn's, in Newcastle, Mr. Scott, the engineer, told me they had one of our gauges on one of their boilers for eleven years, which had continued true during the whole of that time, while gauges of other makers had become quite incorrect after a space of two years.

Mr. Dawson.—The Secretary's inquiry was as to the quality of the steel.

Mr. Budenberg.—That is decidedly the most important part of our gauges, namely, the quality and the tempering of the steel; and the secret of our success lies in the fact that we have had all the springs tempered by one man. Mr. Shobelt, who is present, is one of our oldest hands, and he can tell you that the making and the tempering of the plates, and the making of the socket-joints, are the most difficult and, at the same time, most important points in our gauges. We have only employed one hand for each of these parts, and have never deviated from this rule. By practising things in this way, we have been able to produce a good article; but had we employed a new man every fortnight or so, we would never have made a good gauge. The corrugated steel plates are tempered in oil; and this is a nice operation; for they must not be too hard, and yet they must be hard enough. The other parts, however, must also be well made; for although the steel plate were perfect, if the other parts were not made carefully, the gauge would not move freely, and therefore not indicate correctly. According to our experience, no metal will do for the spring except steel, and we invariably use cold drawn Sheffield steel.

Mr. Maxwell Scott.—I consider it a very satisfactory point that these gauges will throw themselves out of gear in case a pressure has been attained beyond that which they are made to indicate. This feature, I think, is not generally known; for although Mr. Budenberg has several times called on me with these gauges, he never mentioned that circumstance to me before. I should like to ask the method of

forming the corrugations in the steel plate, whether they are stamped as candlesticks and such things are done, or otherwise? I should like to know also the thickness of the steel-plates, and how the difference in the thickness of different plates is compensated for in the graduation of the dial, whether by the tempering, or by the hair spring in connexion with the index?

Mr. Budenberg.—The fact is, we require different thicknesses of steel for gauges of different range of pressure, and we have a great deal of trouble at times to get steel of the thickness we want it. I think it is No. 36 (wire gauge) we generally use; that is the finest steel we use, and we have had a great deal of trouble to get it so fine. We had at one time an order from Mr. Collett, of the St. Katharine Dock Company, to make a gauge to indicate the pressures of a column of water ranging up to four feet. The lowest point of the reservoir was at an elevation of eleven feet, and he had an idea that the index-hand should go thrice around the dial for these eleven feet; and that for the four feet, of which he desired to register the varying heights, it should make a complete revolution, and indicate every fourth of an inch of height of water. We tried to make the gauge as proposed to us, but could not succeed; and Mr. Schaeffer at last accomplished it in a different way. Some of the teeth of the quadrant were cut away, so that it should not begin to indicate until the eleven feet of water were on; and in this manner it has been working satisfactorily for four years. As for the plates, they are stamped.

Mr. M. Scott.—Would not a column of mercury be better for such a purpose?

Mr. Budenberg.—I thought so too at the time, but it is now made and working well at this time, as I may refer you to Mr. Collett, of the St. Katharine Docks. Through his recommendation, based on the working of this gauge, we have our gauges in use everywhere in these docks. Mr. Anderson, of Woolwich Arsenal, is also very favorable to them, and he has them in use extensively throughout the gun factory.

Mr. Scott.—How do you compensate for different degrees of deflection of different thicknesses of plates in the gauges?

Mr. Budenberg.—We have to mark the divisions of the dial for every single pound of the range, by testing with a mercury column; we try them very often over, and we mark off every single pound. Every gauge is marked off in this way; we could not make two gauges to one pattern. There are no two dials exactly alike; it is with them just as with human faces, they look sometimes very like one another, but there is a difference when you examine them.

Mr. Clay.—It would be very difficult to manufacture the plates of the same thickness.

Mr. Budenberg.—This spring has no compensating effect; every plate is tried separately. It is often necessary to put the markings out again; we have to go over this operation several times before we can put the pressures on the dial finally.

Mr. Smith.—I should rather have had a description of different kinds

of gauges than a description of Mr. Schaeffer's gauge. Mr. Schaeffer's gauges, like others, are difficult to repair; and I think it would be a good thing to use a relief-valve like that proposed by Mr. Dewrance, if it was possible to make the valve so as to blow a whistle when it was open, and thus indicate that the limit of safe pressure had been exceeded. There is such a variety of gauges in use, that I do not know the difference between them. I should have liked to have heard from our Secretary, who is so well versed in all these matters, the history of pressure gauges, and their peculiarities. Its cheapness is no doubt a recommendation to Mr. Schaeffer's gauge. This may be accounted for by its coming from Germany, where labor is cheaper than with us, but I know that the gauge is really an excellent one. The mercury column is as good a gauge as can be constructed, and I have been told that an improved mercurial gauge has been introduced. I should have liked to have heard a description of it.

Mr. Birckel.—I think it is too much of Mr. Smith to expect that Mr. Budenberg will come here to blow anybody else's whistle but his own. There are so many different gauges, both in use and out of use, that it would be very difficult for me to go into the history of steam gauge construction. I believe that the two principal gauges known are Schaeffer's and Bourdon's. There is Smith's, and various others, but I do not know the peculiarities of their construction. The principle of construction of Bourdon's gauge has been illustrated to the meeting to-night, as one of these gauges has been passed round the room. The mode of action of Bourdon's tube is to partly uncoil itself under an internal pressure, and the extent to which it is straightened is registered in much the same way as in Schaeffer's gauge.

Mr. Budenberg.—The principle of Bourdon's is so far different from ours, that in the latter the elastic medium is a plate, and in the other it is a tube, and the expansion or uncoiling of the tube turns the index.

Mr. Birckel.—Mr. Smith was saying that the mercurial gauge was as good as any other gauge; but I think it right to state that the mercury gauge is the standard of this, and should be the standard of any other gauge, so that when you measure pressures by means of this gauge, you only read the indications transferred from the open mercurial gauge to this one.

Mr. Clay.—There was a gauge invented by Mr. Alexander Allan; probably Mr. Grey can enlighten us about it.

Mr. Budenberg.—It is not much in use, except only on the locomotives of the line with which he is connected. It is filled with water, I believe, and is something like a closed mercurial gauge, or compressed air gauge, only the medium here is filled with water. There is always a deal of mischief in air gauges, and on the Continent they are entirely condemned. In Prussia you would not be allowed to put one of them on a boiler. The present law in Prussia, which I believe to be quite good, is, that you must have a mercury column in every boiler house. You may have a gauge such as ours on every boiler, but you must have also a mercury gauge connected with the others, and so

arranged that they each and all may be shut off and tested severally, in order to ascertain whether they are working alike, and in harmony with the mercurial gauge. I have a copy of the law with me, and I think no objection to it can be seriously made. It says; "The law that each boiler must have a separate gauge remains in force, but the choice of construction is free, and we recommend, on account of their practicability, and because they can easily be read off, the use of spring gauges, but we require them to be often compared with the controlling gauge." That is to say, suppose you have twelve boilers, every boiler would have one gauge; and in a corner of the house an open mercurial column is placed, and is connected with all these gauges. You have a tap to shut off each of them, but from time to time you have to test them, or perhaps the inspector comes round and sees whether they are all working alike. That is the present Prussian law.

On the Wear and Tear of Steam Boilers. By FREDERICK ARTHUR PAGET, Esq., C.E.

(Continued from page 20.)

From the Journal of the Society of Arts, No. 649.

2.—*The Mechanical Effects of the Heat.*

While a maximum of stiffness to the mechanical action of the pressure is required in a steam boiler, a maximum of flexibility to the irresistible mechanical force of heat is of no less importance. For instance, a great advantage of some of the forms of strengthening rings for internal flues is that they allow the use of thinner plates; together forming a structure of great flexibility to complicated thermal influences. The longitudinal expansion of inside flues like this is taken up by a slight spring or swagging at each joint, and the end plates of the shell are not unduly strained by the combined efforts of the internal pressure and the expansion due to heat. This is one way in which defective circulation, or a sudden current of cold air or of water, can act on the structure, by unequally straining the plates; and, although it seems probable that the effects said to have been thus produced, are, to some extent, due to other causes, they point to the importance of keeping the temperature of the plates as low as possible. One protection against effects of this kind is the gradual diffusion of heat, produced by its conduction to and from the different plates. It is a general belief with engineers that a pressure of steam strains a boiler more than cold hydraulic pressure; but it is unsettled as to what amount and in what exact way. The basis of an examination of the kind would have to be sought in an exact determination of the temperature of a plate which is transmitting the heat to the water, and this has not yet been determined with any accuracy. The fact is, as is remarked by M. Péclet, who has given great attention to these questions, the different phenomena involved are extremely complicated. It is clear that the plates must always be at a higher temperature

than the water, as it is by the difference of temperature of the two surfaces of the plate that it is traversed by the heat. He supposes that, though the plate is inversely as its thickness (while it is directly as the surface and as the difference of temperature between the outside and inside faces), yet the flow of heat would be the same through a thicker plate, from the greater difference of temperature between the two surfaces.* He does not seem, however, to be aware of the important law demonstrated by Mr. J. D. Forbes, that the conducting power of, for instance, wrought iron, rapidly diminishes at the higher temperatures. At 200° C. it has little more than one-half the conducting power it has at 0°.† At yet higher temperatures it might probably be proved, if an applicable instrument for registering higher temperatures were in existence, that the powers of conduction are still less. Some of Mr. Péclet's experiments also seem to be vitiated by his disregard of Dr. Joule's discovery that water is heated by being mechanically stirred up. It is, however, certain that water can only moisten a metallic plate when at a lower temperature than 171° C. As soon as the water gets thus repelled, the heat radiated by the metal is reflected back from the surface of the liquid; the metal gets hotter and hotter, with a corresponding diminution of its conducting powers; its outside, exposed to the fire, would more or less oxidize, and with a similar result; and a like effect is produced on the inside—on the roughened surface of which incrustation would rapidly adhere, forming a calcareous coating, conducting with about sixteen times less power than iron.‡ All these tendencies are of a progressive character, leading to very high temperatures in the plate, even to a red-heat. This tends to explain how rivet-heads close to the fire are soon burnt away by the friction of the current of heated gases on the red-hot metal; how thick fire boxes are sooner burnt out than lighter ones, the process being often arrested at a certain thickness; how internal flues of thick plates so often give trouble; how externally fired boilers are most deteriorated at the corners from the junction of the three plates; and similar results well known to practical men. Another proof that thin plates conduct more heat than thick plates is afforded by some experiments lately made in Prussia, with two egg-end boilers, exactly similar in every respect, except that one was constructed of steel plate $\frac{1}{4}$-inch thick, while the other was of wrought iron about $\frac{1}{2}$-inch thick. The steam generating power of the steel boiler was to that of iron as 127·49 to 100§—a result which can only be accounted for by the thickness of the plates. Thick plates are also more liable to blisters, one of which would considerably diminish the conduction power of the spot where it happened to form.

* Traité de la Chaleur. Vol. II, page 393.

† Royal Society of Edinburgh, 28th April, 1862. "Experimental Inquiry into the Laws of the Conduction of Heat in Bars, and into the conducting power of Wrought Iron."

‡ Traité de la Chaleur. Vol. I, page 391.

§ Verhandlungen des Vereins zur Beförderung des Gewerbfleisses in Preussen, 1862, p. 140.

While it is certain that boiler plates can assume very high temperatures, even up to red-heat, authorities differ as to the diminution of ultimate strength which is caused by heat, while its effect on the elasticity of the plate has been scarcely attended to. The experiments on the ultimate tenacity of iron at high temperatures, conducted by Baudrimont,* Seguin, and the Franklin Institute, can scarcely be looked upon as of much value, for they were made on a very small scale, and with no regard to the temporary and permament elongations—or to the effect of heat on the elasticity and ductility.

Mr. Fairbairn† observed no effect on the strength of plate iron up to almost 400° F. At a "scarcely red" heat the breaking weight of plates was reduced to 16·978 tons from 21 tons at 60° F.; while at a "dull red" it was only 13·621 tons. MM. Tréméry and P. Saint Brice,‡ aided by the celebrated Cagniard Latour, found that at nominally the same temperature (*rouge sombre*), a bar of iron was reduced in strength to one-sixth of its strength when cold. This is much greater diminution of strength than that found by Mr. Fairbairn. Apart from other causes this might easily be due to the fact that incandescent iron affords a different tinge during a dull day to what it does in a clear light. In fact, the great impediment to all these investigations is the want of a thermometer for high temperatures; but M. Tréméry's result is perhaps more conformable with daily experience. Mr. Fairbairn's data would show that the ultimate strength of wrought iron is reduced to about one-half; but M. Tréméry's result explains the generally instantaneous collapse of flues when red-hot, and which have been, of course, originally calculated to a factor of safety of *six*.

A most important question is the effect of temperatures, whether high or low, on the elasticity of the material—whether iron will take a permanent set with greater facility at a high temperature? These data are really more important than those on the ultimate strength, as they would show the influence of temperature on the elastic limit. Here again is a vacancy in existing knowledge, which can scarcely be said to be filled up by the few experiments of the late M. Wertheim on very small wires.§ He found, however, that the elasticity of small steel and iron wire "increases from 15° C. to 100°, but at 200° it is not merely less than at 100°, but sometimes even less than at the ordinary temperature."

There is, however, another important point with respect to wrought iron, which has scarcely received the attention it deserves. As would appear from a number of phenomena, there seems to be a sort of thermal elastic limit with iron. When heated, and when its consequent dilatation of volume does not exceed that which corresponds to (perhaps) boiling point, it returns to its original dimensions. Beyond a certain

* "Annales de Chimie et de Physique," 3, s. 30, page 304, 1850.

† On the Tensile Strength of Wrought Iron at Various Temperatures. Reports British Association, 1856, page 405.

‡ Annales des Mines. 2 serie. Vol. III, page 513.

§ Comptes Rendus, xix, 231.

temperature it does not contract again to its pristine volume, but takes a permanent dilatation in consequence, apparently, of its elastic limits having been exceeded. A number of observers* have determined the fact with cast iron, and though wrought iron has not been expressly investigated in this direction, there is no doubt that it exhibits a similar behaviour. Thus, a number of years ago,† an Austrian engineer named C. Kohn, remarked that a boiler about 12 metres long and 1·57 in diameter, with a thickness of plate of 0·011, permanently expanded, at a temperature corresponding to a steam pressure, of 5 atmospheres, (153° C.) by 0·07193, and did not, when cold, return to its original dimensions. The same thing has been noticed, by means of very accurate measurements, with other boilers. A number of experiments by Lt. Col. H. Clerk, of Woolwich, on wrought iron cylinders and plates,‡ bear distinct evidence to a dilatation of volume in wrought iron, when repeatedly heated and suddenly cooled. In experiment 7, for instance, "two flat pieces of wrought iron, each 12 inches long, 6 inches deep, and ½-inch thick, were heated and cooled 20 times, one being immersed to half, and the other to two-thirds, its depth in water. That immersed one-half contracted or became indented on the ends fully ·3 inch; the other had similar indentations, but only to one-half the amount. They both turned up into the form of an arc," the *convex* side of which appeared in the portion heated and cooled. Unfortunately, the specific gravities of the different portions were not tried by Colonel Clerk. A succession of trials of the kind produced cracks in the metal, thus explaining how boiler plates are cracked by imperfect circulation and by cold feed-water let in near the fire; and, the thicker the plate, the more permanent dilatation of volume and consequent danger. Mr. Kirkaldy found that "iron highly heated and suddenly cooled in water, is hardened," being injured, in fact, if not afterwards hammered or rolled. This permanent dilatation of volume must be necessarily accompanied with a diminution of specific gravity, thus affording another close analogy, betweeen straining iron by loads in excess of the mechanical elastic limits, and straining by heat. Lajerhelm§ found, long ago, that the specific gravity of iron is diminished by strains in excess of the limit of elasticity, and this result has been completely confirmed by Mr. Kirkaldy's numerous experiments. The smith calls iron "burnt" which has been rendered brittle in working through the often repeated applications of heat, or through too high a temperature. Iron rendered brittle by strains in excess of the limit of elasticity has been long popularly termed "crystallized." Both these states are accompanied with a dilatation of volume and attendant hardness and brittleness, and both seem to be referable to very similar causes. In fact, a very general belief exists that very ductile good iron, used in the form of a steam boiler, soon gets brittle. There are some applications of metal to a steam boiler peculiarly liable to

* Percy's Metallurgy, vol. ii, page 872.

† Technologiste. 1850-51, page 102.

‡ Proceedings of the Royal Society, March 5, 1863.

§ Poggendorf's Annalen, 2, s., vol. ii., page 488.

be strained beyond the limits of elasticity; by mechanical force, by the mechanical force of expansion and contraction, and by dilatation of volume through heat—all three acting simultaneously. Such is the case with fire-box stay-bolts. Accordingly, they are found to get very brittle when of wrought iron—which is a much less ductile metal than copper. Mr. Z. Colburn states that he has "frequently found these stays (where made of wrought iron) to be as brittle, after a few years use, as coarse cast iron." He has "broken them off from the sides of old fire-boxes, sometimes with a blow no harder than would be required to break a peach-stone."*

The Chemical Effects of the Incandescent Fuel.

Whatever physical changes may be induced in iron by the long continuance of a high temperature which is not succeeded by the application of the impact of the hammer or the pressure of the rolls, it is certain that long-continued red-heat leads to the loss of its metallic consistency. Its surface gets converted to a greater or less depth into forge scales, which, according to Berthier, consist of a crystallized compound of peroxide and protoxide of iron. The mechanical action of the gases—and especially of the free oxygen contained in every flame—forced at a high velocity by the draft past the more or less heated plates, would also aid these chemical combinations—upon the same principle as iron filings, thrown through a gas flame, burn in the air; and upon the same mechanical principle as the incandescent lime is worn away by the flame of the oxyhydrogen blow-pipe. These actions would take place with any fuel, even with pure charcoal. But when mineral fuel, which mostly contains more or less iron pyrites, is used, there is much more danger to the plates, especially over the fire, in getting red-hot, as the flames would then hold sulphurous acid, and often volatilised sulphur. A familiar illustration of an action of this kind is afforded by the fact that a piece of red-hot iron plate can be easily bored through by means of a stick of sulphur the combination forming sulphide of iron. Dr. Schafhaeutl, of Munich, has given great attention to the changes in plates subjected to the action of fire; twenty-five years ago he read a paper before the Institution of Civil Engineers,† and more recently he has published an essay, both on this subject, in a Munich periodical.‡ He has brought forward a number of facts, founded on chemical analyses of plates of exploded boilers, showing the danger, due to chemical action alone, when the plates of a boiler become red-hot. He notices that the iron of the inside of the plates, in getting red-hot decomposes the water, and combines with the oxygen thus freed. It also loses some of its carbon. The outside combines with the free oxygen and with any sulphurous acid in the flame. He states that iron made with pit coal is much more affected than charcoal made iron; becoming laminated at the original joints in the pile out of which the plate has been rolled. It is possible that

* Steam Boiler Explosions, 1860, p. 32.

† Transactions of the Institution of Civil Engineers. Vol. III, 1840, p. 435.

‡ Bairisches Kunst und Gewerbeblatt. June, 1863.

portions of oxide are carried into these joints, and it is at any rate certain that iron gives way easiest at these places. This points to the great value of really homogeneous plates, such as those of cast steel, in which homogeneity has been obtained by the only known means of fusion. The remarkable diminution of elasticity and of tenacity caused by the combination of the red-hot iron with sulphur; the absence of all elasticity and tenacity in the oxides of iron, show that, even if a flue do not at once collapse, or a shell explode, through getting red-hot, the boiler is more or less injured every time it gets overheated. A defective circulation, by permitting such a temperature as to drive the water off the plate, would soon lead to local injury. Particular spots in externally fired cylindrical boilers are sometimes, as is stated by Mr. L. Fletcher, of Manchester, thus affected, and in an apparently mysterious way. A new boiler in which a heap of rags were accidently forgotten, had the spot burnt out in a few days,* doubtless through the resulting defective circulation and its consequences. The plates just above the fire of internal flues also suffer in this manner. It is perhaps possible that turned joints, secured by bolts, and allowing an occasional reversing, or rather rotating, of the ring, might, in some cases, be here of service. At any rate, universal experience proves that the thicker the plate the easier does it get red-hot; and these chemical facts also point to the desirability of a minimum of thickness. In fact, the wearing away of the plates through these causes, if mechanically strong against pressure, often gets arrested at a certain thickness. In Germany and France, some of the best manufacturers still make the plate over the fire of, for instance, inside flues, slightly thicker than anywhere else; but the combined chemical and mechanical actions of the heated fuel cause most wear and tear in a thick plate, and thus justify American practice in this respect. In that country, fire-box plates of good charcoal iron are made only $\frac{5}{16}$ or $\frac{1}{4}$ of an inch thick, and with stays four inches apart, give good results under nearly 150 lbs. steam pressure.

(To be continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

On Chemistry Applied to the Arts. By Dr. F. Crace Calvert, F.R.S., F.C.S.

From the London Chemical News, No. 242.
Continued from vol. xlix, page 329.

Leather.—The art of the currier. Morocco, Russia, and patent leathers. The art of tawing skins. Chamois and glove skins. Parchment. *Hair*, its composition and dyeing. *Wool*, its washing, scouring, bleaching, and dyeing. *Silk*, its adulterations and conditioning.

Lecture III.

Delivered on Thursday evening, April 14, 1864.

I shall have to crave the indulgence and patience of my audience during this lecture, as it will chiefly consist of descriptions of processes

* Péclet, Traité de la Chaleur. Vol. II, page 73.

for the most part well known to manufacturers and others engaged in the leather trade. Thus the art of currying, which is applied principally to such leathers as are intended for the upper parts of shoes, for harness, &c., is carried on at the present day nearly as it was fifty years ago, and still is but little known to the public.

Currying.—The objects in view in currying leather are several: to give it elasticity—to render it nearly impermeable—to impart to it a black or other color, and, lastly, to reduce it to uniform thickness. These colors are imparted by the following processes:—After the leather obtained from hides, or the thicker qualities of skins, has been damped, it is placed on a stone surface and energetically rubbed—first with a stone, then with a special kind of knife called a slicker, and lastly with a hard brush. The leather is then ready to be stuffed or dubbed, which consists in covering it on the fleshy side with tallow, and hanging it in a moderately warm room; and as the water contained in the leather evaporates, the fatty matter penetrates into the substance of the leather and replaces it. The dubbing process is then repeated on the other side of the leather, which is now ready to be softened and rendered flexible, which is effected by rubbing it with a tool called a pummel. The leather then undergoes the last mechanical operation, which reduces it to uniformity of thickness by shaving off the inequalities of its surface by means of a peculiarly shaped knife called a slicker. The greatest part of the curried leather is blackened on the grain side by rubbing it with grease and lamp-black, and lastly brushing it over with a mixture of grease and glue. I believe that some kinds of curried leather are dyed by a purely chemical process, in rubbing the tanned skin, first with iron liquor, and then with a solution of gall-nuts or other tanning substance. The most tedious of the foregoing processes is that of dubbing, which has been greatly improved of late years by the Americans. The scoured skins are placed in a large revolving drum, of ten or twelve feet diameter, and lined inside with wooden pegs. A certain quantity of tallow is then introduced and the whole set in motion, and whilst the hides are thus tossed about, a current of warm air is passed through the drums, which carries off the moisture and allows the grease to penetrate the hide. By this means thick hide leather can be stuffed in four or five days.

Split Leather.—A large branch of trade has sprung up within a few years owing to the invention of machinery for splitting hides, skins, and kips, by which, although the quantity of leather has been considerably increased, I am afraid it is at the expense of its quality.

Fancy Leathers.—Allow me now to give you a slight insight into the methods of preparing various fancy leathers, such as Morocco, Russia enamelled, tawed, or kid leather, used for soldiers' belts, gloves, &c., and, lastly, oiled leathers used for wash-leather, gloves, &c. Until the middle of the eighteenth century, Morocco leather was wholly imported from that country, for it was in 1735 that the first Morocco works were established in Paris, and similar manufactories were soon set up in various parts of the Continent and in this country. The process by which Morocco leather is prepared is as follows: The

goat and sheep skins, which are especially used for this branch of manufacture, are softened, fleshed unhaired, and raised or swelled by methods similar to those already described, but one essential element of success in this kind of leather, lies in the perfect removal of all lime from the skins, which is effected by plunging the well-washed skins in a bath of bran or rye flour, which has been allowed to enter into a state of fermentation. The result is, that the lactic and acetic acids generated by fermentation of the amylaceous substances combine with the lime and remove it from the skins. The other essential point is the mode of tanning the skins. Each skin is sewn so as to form a bag, and filled, through a small opening, with a strong decoction of sumac, and after the aperture has been closed, the skins are thrown into a large vat containing also a decoction of the same material, After several hours they are taken out, emptied, and the operation is repeated. To render these skins ready for commerce it is necessary to wash, clean, and dye them. The latter operation was formerly tedious, and required great skill, but since the introduction of tar colors, the affinity of which for animal matters is so great, it has become comparatively easy. The skins, after they are dyed, are oiled, slightly curried, and the peculiar grain, characteristic of Morocco leather, is imparted to it by means of grooved balls or rollers. There are two inferior kinds of Morocco leather manufactured, viz: those called *roan*, prepared in a similar way to Morocco, but not grained, and *skivers*, also prepared in the same manner, but from split sheep skins. I owe to the kindness of Mr. Warren De la Rue, the beautiful specimens of leather before me, which will enable you to appreciate the various qualities of these interesting productions.

Russia Leather.—The great esteem in which this leather is held is owing to its extreme softness and strength, its impermeability, and resistance to mildew, which latter property is imparted to it by the use of a peculiar oil in its currying, that is birch-tree oil, the odor of which is well-known as a distinguishing feature of Russia leather. As to its preparation I will merely state that it is very similar to that of Morocco, with these differences, that hot solutions of willow bark are used instead of sumac; that it is generally dyed with sandal wood and a decoction of alum; and, lastly, as already stated, the birch-tree oil is used in currying it.

Enamel Leather.—This class of leather is usually prepared with calf and sheep skins tanned in the ordinary manner. They are dyed black by rubbing them over with a decoction of logwood, and then iron liquor or acetate of iron. The leather is softened with a little oil, and is ready to receive a varnish, which is applied by means of a brush, and composed of bitumen of Judea, copal varnish, oil varnish, turpentine, and boiled oil.

Tawed or Kid Leathers.—The manufacture of this class of leathers differs entirely from those already described, as their preservative qualities are imparted by quite different substances from those used with other leathers, the preservative action of the tannin being substituted by that of a mixture of alum and common salt. Let us examine

together a few points connected with the production of this class of leather. One of the most interesting characteristics is the method of unhairing sheep, lamb, and kid skins, after they have been well washed and fleshed on the beam. The old process of unhairing by smearing on the fleshy side with a milk of lime, was improved by mixing with the lime a certain amount of orpiment, or sulphuret of arsenic, but Mr. Robert Warrington having ascertained that the rapid removal of hair in this case was not due to the arsenic, but to the formation of sulphuret of calcium, proposed, with great foresight, the following mixture as a substitute for the dangerous and poisonous substance called orpiment—viz: three parts of poly-sulphuret of sodium, ten parts of slacked lime, and ten parts of starch. The poly-sulphuret of sodium may be advantageously replaced by the poly-sulphyret of calcium. The skins, unhaired by any of these processes, are now ready to be placed in a bran or rye bath, as with Morocco leather, or in a weak solution of vitriol, to remove, as already stated, the lime. After the lime has been thoroughly removed from the skins, they are dipped in what is called the white bath, which is composed, for 100 skins, of 13 to 20 lbs. of alum, and 4 to 5 lbs. of chloride of sodium or common salt, and the skins are either worked slowly in this bath or introduced into a revolving cylinder to facilitate the penetration of the preservative agent, which, according to Berzelius, is chloride of aluminium resulting from the action of the chloride of sodium on the alum. When the manufacturer judges that the skins have been sufficiently impregnated with the above mixture, he introduces them into a bath composed of alum and salt in the same proportions, but to which is added 20 lbs. of rye flour and 50 eggs for 100 skins. After remaining a few hours they are removed, and allowed to dry for about fifteen days, and are then softened by working them with a peculiar iron tool, and the white surface which characterizes that class of leather is communicated to them by stretching them on a frame and rubbing them with a pumicestone. A large quantity of tawed leathers are also preserved retaining their hair, which is done by simply suppressing the unhairing and rubbing processes.

Chamois, Wash, or Oiled Leather.—This class of leathers are named from the fact that formerly they were exclusively produced from the skin of the chamois, but at the present day sheep, calf, and deer skins, and even split thin hides, are manufactured into this kind of leather. I should also state that the employment of this kind of leather has greatly decreased of late years, owing to the general substitution of woolen fabrics in articles of clothing. You will see by the following description that the preparation of this class of leather differs entirely from those previously detailed; the conversion of skins into leather, or from a substance subject to putrefaction to one free from that liability, being no longer affected by tannin, as in the case of hides, and Morocco and Russia leathers, or by the use of mineral salts, as in the case of tawed leathers, but by that of fatty matters, especially animal oils, such as sperm. The skins are prepared in the same manner as for tawed leathers, and then submitted to what is called the

prizing operation, which consists in rubbing the hair side of the skin with pumice-stone and a blunt tool or knife, until the whole of the rough appearance is removed, and the skin has acquired a uniform thickness. They are then worked on the peg until the great excess of moisture has been wrung out, and plunged into the trough of a fulling mill, to the action of the wooden hammers of which they are subjected until nearly dry. They are then placed on a table and oiled, and several of them, after being rolled together, are replaced in the trough of the fulling mill. When the oil has been thus worked into the substance of the skins, they are removed, exposed to the atmosphere, again oiled and, once more subjected to the fulling mill; after which they are placed in a moderately heated room for a day or two, the object of which is two-fold, viz: to facilitate the evaporation of water and the penetration of the oil, and to create a slight fermentation, by which the composition of certain of the organic substances have undergone such modification as to enable them to combine in a permanent manner with the fatty matters. These processes are repeated until the manufacturer deems the leather sufficiently prepared to be fit to undergo the following operations, viz: to be immersed for several hours in a caustic lye bath, to remove the excess of oily matter, washed, and pegged. It is only necessary to stretch the leather on a table, then on a horse, and lastly between rollers, after which it is ready for the market. The ordinary buff color of these leathers is communicated by dipping them, previously to the finishing processes, into a weak solution of sumac. Before speaking of the further processes necessary to fit these leathers for the glove manufacturer, allow me to have the pleasure of describing that of Mr. C. A. Preller, whose mode of preparing leather is very interesting, owing to the rapidity with which he converts hides into leather, and also to the remarkable toughness which his leather possesses. To attain these desirable ends Mr. Preller proceeds as follows: The hides are washed, slightly limed, unhaired, fleshed, and partially dried; they are then smeared with a mixture, made of fatty matters and rye flour, which having been prepared a few days previously has entered into fermentation, and which has so modified the fatty matters as to render them more susceptible of immediate absorption by the hide. I think that this feature of Mr. Preller's plan deserves the serious notice of all engaged in the manufacture of oiled leathers, as it appears to prove that fatty acids (or modified fatty matters) are better suited for combination with skins than neutral fats. The hides, with additional fatty matters, are then introduced into the large American drums, previously noticed in speaking of currying, and after four days they are removed, washed in an alkaline fluid, worked with a pummel and slicker, and after being dried they are ready for market.

Gloves.—The manufacture of this article is now a most important branch of trade, and is the means of giving employment to large numbers of people in several towns in this country as well as on the Continent. To render the above-mentioned oiled leather sufficiently soft and pliable for gloves it is necessary to submit it to the following fur-

ther operations: The chamois, kid, or other skins are rubbed over with a solution composed of one pound of soap, dissolved in half a gallon of water, to which is added $1\frac{1}{2}$ lbs. of rapeseed oil and twenty yolks of eggs, or, what has been recently found to answer better than eggs, a quantity of the brains of animals reduced to pulp. The use of the two latter substances is extremely interesting in a scientific point of view, for they both contain a peculiar nitrogenated matter called vitalline, and special fatty matters called oleophosphoric and phosphoglyceric acids, which doubtless, by their peculiar composition, communicate to the skins those properties which characterize this class of leather. The skins are then washed and dyed in various colors, after which they are softened and rubbed with an instrument adapted to slightly raise the surface, and give it that well-known velvetty appearance belonging to glove skins. I shall not take up your time by entering into the details of dyeing these leathers, but describe the following process for bleaching them:

Bleaching of Skins.—The only process known until recently for imperfectly bleaching chamois and glove skins was that of submitting them to the influence of the fumes of sulphur in combustion or sulphurous acid, but latterly two modes of attaining that object have been proposed. The first consists in dipping skins for two days, in a weak solution of neutral hypochlorite of soda, washing, drying, and rubbing them with soap and oil. The second mode is to dip glove skins into a solution of permanganate of potash, when they soon assume a brownish color, due to the liberation of the oxygen of the permanganate of potash, and the fixation of the hydrate of sesquioxide of manganese by the skin. The skins so acted on are washed and then dipped in a solution of sulphurous acid, which becomes converted into sulphuric acid by the action of the oxygen of the sesquioxide of manganese, and the protoxide thus produced unites with the sulphuric acid, which is soluble in water. The skins thus bleached when dressed are ready for market.

Gilding of Leather.—The usual mode of ornamenting leather with gold is to apply, in such parts as are desired, a thick solution of albumen, covering those parts with gold leaf, and applying a hot iron, when the albumen is coagulated and fixes the gold. This plan is objectionable when the goods are intended for shipment, and the following method, lately proposed, is far preferable: On the parts required to be gilt, a mixture, composed of five parts of copal and one of mastic, are spread; a gentle heat is applied, and when the resins are melted the gold leaf is spread upon them.

Parchment.—There are two distinct qualities of this valuable material, which has been used from time immemorial as a means of preserving records. The best quality is prepared from young lamb, kid, and goat skins, and the second quality from calf, wolf, ass, and sheep skins. To make parchment, the following is the process: The skins are stretched on strong rectangular frames, limed, unhaired, fleshed very carefully, and rubbed with pumice-stone until the skins have acquired the proper thickness. They are then dried very carefully in the shade.

Dialysis.—Thomas Graham, Esq., Master of the Mint, has lately drawn the attention of the scientific world to a most remarkable property possessed by organic membranes of separating, when in solution, crystallizable bodies from those which are not so. The former he names crystalloids, and the latter colloids. For instance, if a solution of sugar (crystalloid) is mixed with one of gum (colloid) and placed in the vessel, the bottom of which consists of a septum of animal or vegetable parchment, the crystalloid sugar will pass through the membrane into the surrounding water, whilst the colloid gum will remain in the vessel. Again, if solutions of iodide of potassium and albumen be mixed together, the iodide of potassium will diffuse itself through the membrane, which the albumen will not do. Also, if to an alkaline solution of silicate of soda, weak hydrochloric acid be cautiously added, chloride of sodium will be produced, and the silica will remain in solution; and if such a solution be placed in the dialyser, the chloride of sodium (the crystalloid) will diffuse itself through the membrane, while the silica (the colloid) will remain behind. It is impossible to calculate the immense service which the discovery of these facts by Mr. Graham will render to physiology, toxicology, or to manufactures, as, in fact, every day new applications of it are being made in these various departments of human research. Thus, to give an example which has special reference to these lectures, I have lately seen it proposed by Mr. A. Whitlaw to place salted meat in large dialysers, when it is stated that the salt only will be removed, leaving all the nutritive properties of the meat undiminished. Mr. Whitlaw also proposes to dialyse the brine in which meat has been salted, and thus to remove the salt, leaving the juice of the meat available for use, while the salt is again in condition to be employed as before.

It will now be my agreeable duty to examine with you a few facts relating to hair and wool. It is interesting to observe that hair, wool, feathers, nails, and claws may be all considered as prolongations of the epidermis, and present nearly the same chemical composition, as will be seen by the following table:

	Epidermis of man.	Hide.	Man's nails.	Hair.	Quill.	Horse's hoofs.	Scale of reptile.
Carbon, ...	50·89	50·89	51·09	50·14	52·43	50·40	53·60
Hydrogen, . . .	6·81	6·78	6·12	6·67	7·22	7·00	7·20
Nitrogen, . . .	17·22	17·25	16·91	17·94	17·93	16·70	16·30
Oxygen and Sulphur,	25·63	25·08	25·88	25·25	22·42	25·90	22·90
	100·00	100·00	100·00	100·00	100·00	100·00	100·00

These substances have also this peculiarity, that, notwithstanding their great richness in organic matters, they are extremely slow to decompose.

Hair.—The only real point of interest connected with hair appears

to me to be the question as to what its various colors are to be ascribed, and I regret that here I can only give conjectures and not positive facts. Vauquelin and Fourcroy, who analyzed hair most carefully half a century ago, stated that hairs were hollow cylindrical tubes filled with oils of various colors; but Gmelin and others state that the coloration of hairs is due to the different proportions of sulphur that they contain.

QUANTITY OF SULPHUR IN HAIR.

Brown,	4·98
Black,	4·85
Red,	5·02
Grey,	4·03

Recently Mr. Barreswil has published a paper, in which he states that the coloration of hairs is probably due to the proportion of iron in their composition, and he argues that as iron is the essential element of the coloring matter of blood, it is highly probable that it fulfils the same office with respect to hair. I may state, *en passant*, that also great improvements have lately been made in dyeing human hair. Formerly the patient had to undergo most unpleasant treatment, his head being covered with a paste consisting of three parts of lime, and one of litharge. An oil cap was then applied and the patient left for twelve hours, when the disagreeable operation of removing the mass and clearing the hair was proceeded with. The black dye communicated to the hair in this process was due to the sulphur of the hair combining with the lead of litharge, and forming black sulphuret of lead. The present process consists in cleaning the hair thoroughly with a strong alkaline soap, or a little weak alkali, then carefully applying a solution of nitrate of silver, and lastly a solution of monosulphuret of sodium.

Wool differs from hair chiefly by its property of felting, which it owes to its numerous cross lines or serratures, as they are termed; the finer the wool the greater the number of its serratures. Thus, whilst Mr. Goss has found in the finest Saxony wool 2720 of these serratures in a single inch in length, he only found 2080 in an inch of South Down wool, and 1850 in Leicester. The wool of sheep can be classed under two heads, that is, into long wool and short wool. Certain classes of sheep will maintain the type or quality of their wool under every circumstance. Such are the original types of South Down, Norfolk, and Dorset, all of which are short wool, and all these sheep feed upon fine and short grass. It has been observed that if they are fed upon coarse grass, their wool will also become coarse. This is also true with Welsh, Scotch, and even Spanish merinos. A further proof that this view appears correct is, that the long-wool sheep, such as those of Leicester, Lincoln, and Kent, feed in valleys where grass is long and coarse, In all cases the size of the animal appears also to correspond with their class of food. Another curious fact is the facility with which one type of sheep will merge into another if they change food and climate. Thus many attempts have been made to introduce into France, our Leicester breed, the wool of

which is so remarkable for its fineness, length, and silvery appearance. Still, after four or five years residence there, the wool has lost its valuable qualities. In fact, they are no more the Leicester breed. The coarse wool of sheep, however, such as those of Devonshire, does not appear to be so rapidly influenced by any change of climate which the animal may undergo. The aptitude which various kinds of wool have for dyes is also very interesting. Thus the wool of one kind of sheep will not dye with the same facility as that of another; and wool dyes much more uniformly, if the animal has been washed before shearing than when the washing is performed upon the wool afterwards. Lastly, the wool removed by the liming process before described will be far inferior in dyeing properties to wool taken from the same kind of animal during life. It may be interesting to some present to know the best method of removing these irregularities. I was engaged during my assistantship at the Gobelins in investigating this matter, and I found that the best plan was to steep the wool for twenty-four hours in lime water, and then to pass them through weak hydrochloric acid. Wool, as it leaves the animal, is not fit for either dyeing or spinning. Thus, when wool is washed with water, it yields a large quantity and variety of substances, which in France bear the name of *suint.* The most interesting fact connected with this is, that the 15 per cent. yielded by wool does not contain, as shown by M. Chevreul, any salts of soda, but a large quantity of salts of potash, the greatest part of which is combined with an acid called sudoric; and what increases the interest of this fact is that Messrs. Maumené and Rogelet displayed at the last Exhibition salts of potash which they had obtained commercially from this new source. In fact they have established in several of the large manufacturing centres of France, where considerable quantities of wool are used, factories for the extraction of salts of potash from the *suint*, and they supplied the jury with the following particulars: That a fleece of wool weighing 8 lbs. yielded on the average about 1¼ lb. of dry suint, or sudorate of potash, and this would further yield about seven ounces of pure potash. If it is now considered that there is annually twenty million pounds of wool washed in Rheims, thirty millions at Elbeuf, and four millions at Fourmies, it would appear from this quantity that if it were all subjected to Messrs. Maumené and Rogelet's treatment, about 2½ million pounds of pure potash might be recoverable. For further details on this point see Dr. Hofmann's report on chemical products and processes in the last Exhibition. Wool which has been simply washed, as above described, is not sufficiently free from extraneous matters to be fit for application in manufactures. It is necessary that it should be scoured, for which purpose, on the Continent, it is allowed to remain for some time in putred urine, or weak ammoniacal liquor, but in this country it is placed in strong alkaline of soap, or soft soap passed through rollers to press out the excess of soap, together with the impurities which it removes, well washed, and dried. In these operations wool loses in weight above 50 per cent. when of good quality, and above 30 per cent. when inferior. But even then the wool still retains a certain amount of fatty matters, which it yields to hot alcohol.

The following table, published by M. Chevreul, will give you an idea of the composition of the wool dried (at 212°):

Earthy matters,	27·40
Organic and inorganic salts, soluble in water (*suint*),	32·74
Fatty matters,	8·37
Wool,	31·49
	100·00

Elementary composition, C. 50·66, H. 7·03, N. 17·74, O. 22·32, S. 2·25.

Before proceeding further, I should like to call your attention to the curious fact that the fatty matters of wool are completely different from the fatty matters of the animal itself; thus, whilst the ordinary suet will be saponified by an alkali, the fat of the wool will not undergo that change, the stearine and elearine being only converted into an emulsion. From experiments I have made, I am able to state that the common opinion, that the differences in quality observed in various wools are owing to their fatty matters, is erroneous, as the pure wool obtained as above yielded to the dyer colors as brilliant as those presented by wools in which a part of the fatty matter still remained. Another important fact connected with the composition of wool is the quantity of sulphur it contains, which does not appear to be part of the fibre, as the matter containing it can be removed by a weak alkali without destroying the fibrous appearance of the wool, although its tenacity is greatly impaired, and its power of taking dye considerably diminished. Another remarkable fact is that when wool is bleached by sulphurous acid, the only agent known which will effect that purpose, it becomes incapable of taking many colors, especially the new and brilliant coal tar dyes. The long-disputed question among chemists—how sulphurous acid operates so as to bleach wool?—has lately been solved by Messrs. Leuchs and Weber, who have proved that sulphurous acid unites with the coloring matter of the wool, forming a colorless compound, in proof of which it appears that if the wool is placed in boiling water this colorless compound is dissolved, and the wool regains its susceptibility to dyes, though it is slightly discolored. A slight amount of alkali added to the boiling water greatly facilitates the removal of this artificial sulphuretted compound. In a paper lately published by Mr. Grothe, he states that 100 parts of wool fix, on an average, 0·67 of sulphur, or 1·31 of sulphurous acid to bleach it, and, practically, 100 parts of wool require about five parts sulphur to be burnt to produce the result. I should also state that wool must always be wet before being submitted to the fumes of sulphur, and it is always advantageous to pass it previously through a soap lye or weak alkali. Wool so bleached should always be well washed in cold water to remove the excess of sulphurous acid, which otherwise, if the wool were subsequently exposed to moisture, might be converted into sulphuric acid, and destroy the fibre of the wool. It may be interesting to ladies to know the process used by a French scourer, named Jolly, to restore Cashmere shawls discolored by time. It consists in dipping them in a solution of sulphurous acid, which

bleaches the wool, but does not affect the fast colors with which the fibres composing the patterns of the shawls are dyed. The shawls then only require to be washed and pressed to be restored to their original beauty. There is no doubt in my mind that a solution of sulphurous acid might be substituted for the gas in bleaching wool with advantage and economy, owing to the sulphurous acid being in a more condensed form, and in better condition for effecting the bleaching process. A few years ago I took advantage of the fact that wool contains sulphur to produce upon it an artificial lustre. The woolen goods were passed through a weak boiling solution of acetate of lead, washed carefully in pure water, and submitted to the action of high-pressure steam, when the lead combined with the sulphur of the wool, producing galena, which gave the wool a lustre. The action was regulated by generating, under the influence of steam, nascent sulphuretted hydrogen from a polysulphuret of sodium, which facilitated the object in view. Wool is generally dyed either in the fleece, after undergoing the processes of washing and scouring, or it is first spun into yarn or worsted. To describe all the various methods of dyeing wool would far exceed the limits of this lecture. The operations of spinning wool into yarn or worsted are purely mechanical, and it is not therefore within my province to describe them. The same remark applies also to the manufacture of felt and shoddy, now so extensively carried on in Yorkshire, and I shall therefore merely refer to one or two points having reference to chemistry, such, for instance, as the working up of the wool or the cotton in worn-out fabrics. To recover the wool from such fabrics the process is most simple, consisting simply in immersing them in diluted muriatic acid, and drying them at a temperature of about 220°, by which means the cotton is completely destroyed, the wool remaining unaffected. The material is then submitted to the action of a "devil," which separates and blows away the cotton, leaving the wool ready for being worked up. To remove the vegetable fibre with the view of applying it to the purposes for which it is adapted,—as the paper manufacture, for instance,—the following process has been devised by Mr. F. O. Ward and Captain Wynants. The mixed fabric is submitted to high-pressure steam (60 to 80 ℔s. to the square inch), and under the influence of this high and moist temperature the vegetable fibre remains unchanged, whilst the animal one is so much disorganized that when the rags are removed from the receptacle and dried, and submitted to the action of a bathing machine, the cotton fibre remains intact, whilst the animal matter falls to the bottom of the machine in the form of a dark colored powder mixed with small lumps of the same substance; this residue has been advantageously applied as a manure, by these gentlemen, under the name of "ulmate of ammonia." I am happy to state that chemical science has discovered several means of distinguishing cotton from wool when employed in the same fabric, and even of determining their respective weights in the same; but the aid of the magnifying powers of the microscope is often required in investigating the mixtures of wool with flax, cotton, jute, &c., which are now so extensively and so ingeniously

spun together. The description of these processes, however, would involve so much technicality, and require so much time, that I must not trouble you with their details. The same remarks apply to the means used for distinguishing the materials used in mixed fabrics of silk and cotton, or silk, wool, and cotton.

Silk.—This material has always been highly esteemed, owing to its remarkable durability, and to the beauty of the fabrics produced from it. Thus, the Chinese have used silk from time immemorial, and the Romans held it in such high estimation, that, at the time of the Cæsars, silk was worth its weight in gold. The most interesting fact for us is the introduction of the silkworm into Europe; it is related that in A.D. 555, two monks, returning from the East, concealed some silkworms' eggs in their staves, and having succeeded in rearing the worms, their culture soon spread through Greece and Turkey, and gradually found its way into Italy towards the twelfth century. The silk in use at the present day is chiefly derived from the *Bombyx mori*, but the extensive disease which has, during the last eight or ten years, destroyed very large numbers of the worms, has given rise to great efforts to introduce some new species, two of which, the *Bombyx mylitta*, feeding on the *Palma christi* or castor-oil tree, and the *Bombyx alianthus*, feeding on the plant from which it is named, have been to some extent successful. The material forming the silk is secreted in two glands placed upon the side of the animal's body, whence it passes into an organ called spinaret, on each side of which are two other glands, which secrete a gummy substance, and this uniting with the former forms the silk fibre. Permit me to add here a fact which I think will interest you—viz., the extraordinary weight of silk which a small weight of eggs will yield. Thus, four ounces of eggs will yield 87,900 to 117,000 cocoons; and as, on an average, a pound of silk requires 270 cocoons, the four ounces of eggs will give 422 lbs. of silk, or 100 lbs. of cocoons yield generally 8 lbs., or about 14 per cent. of silk. The production of silk fibre from cocoons is extremely simple. It is effected by placing the cocoons in boiling water which softens or dissolves the gummy matter which binds the fibres together, and the ends of the fibre being detached and placed on a reel, is easily wound. This is the state in which it is usually imported in this country under the name of raw silk. When two or more of these fibres are slightly twisted together they form what it is called tram or weft, and when two of the threads are twisted in opposite directions and laid together they form organzine or warp. To render this substance susceptible of dyeing, it is necessary to remove the gum by an operation called boiling off, which consists simply in boiling the silk for some time in a soap lye, and washing and wringing it well afterwards, in which operation it loses about 21 per cent. The following table will show the chemical composition of silk:

Gelatine,	19·08	Commercial yield, 79 per cent. of silk.
Albumen,	25·47	
Wax and fatty substances,	1·45	
Silk fibre,	54·00	
	100·00	

Fibroine.—Carbon, 48·53; hydrogen, 6·50; nitrogen, 17·35; oxygen and sulphur, 27·62.

Conditioning Silk.—This expression implies the ascertaining of the real commercial value of silk, or, in other words, its condition, and the necessity of this has been so fully admitted that a conditioning house has existed for 40 or 50 years in Lyons, and its advantages have been so fully appreciated that similar establishments have arisen and are well supported in every town on the Continent, where dealings in silk to any amount take place. I may mention, as an instance of the universal adoption of the practice, that even in Crefeld the finest building in the town is the conditioning house. The result is that on the Continent the intervention of the conditioning house between buyer and seller has become quite a matter of course, with the happy result of abolishing a class of dishonorable dealing which is eating like a canker into the silk trade of Great Britain. I cannot understand why the attempts made to introduce this admirable system into our country have hitherto met with so little success, and can only infer that there is an unsoundness in the trade, which places many of the silk manufacturers to a great extent under the control of wealthy merchants, who, it appears, are the chief opponents of conditioning. Otherwise one would suppose that its advantages to all engaged in working up this valuable product are too obvious to require demonstration, for, taking the most lenient view of the matter, the average gain to the manufacturer by conditioning will be not less than five per cent., and this loss (if he does not condition) cannot be recovered in any subsequent stage, so that his foreign competitor has in this respect alone an advantage over him of at least five per cent. Allow me to conclude this lecture by stating in a few words how conditioning is carried on. Silk being an exceedingly hygrometric substance—its moisture varying constantly with the amount of humidity and the temperature of the atmosphere—the first operation is to ascertain the total amount of water it contains, for which purpose samples, carefully selected from the bale when it reaches the conditioning house, are weighed in delicate scales, dried in hot-air stoves, and re-weighed, the excess of moisture (beyond the 10 per cent. admitted to be the average normal quantity) being then easily calculated. The second operation carried out in the conditioning house is that of boiling off the samples dried as above, and again drying and re-weighing, to ascertain the quantity of soap, oil, sugar, acetate of lead, &c., added to give weight, and the result of this operation is to show a loss of 30, 35, and even 40 per cent. instead of about 21 per cent., which is the average amount of natural gum.

(To be continued.)

On the Revivification of Animal Charcoal. By Henry Medlock, Ph.D., F.C.S., M.P.S.

From the London Chemical News, 272.

The principal source of expense in a sugar refinery is that of animal charcoal, and it is a great desideratum to the refiner, commencing with

the use of new animal black, to adopt a means of keeping his coal in good condition, and retaining unimpaired its decolorizing powers after each successive use. I will treat the subject very briefly under the following heads:

1st. The composition of bone and animal charcoal.

2d. Its decolorizing property, and the causes of its becoming inactive.

3d. The means of restoring its primitive powers of absorption and decolorization.

I. The Composition of Bone and Animal Charcoal.—Bone, as is well known to anatomists, is a solid structure composed principally of phosphate of lime and osseine, a modified form of gelatine. The phosphate of lime, or solid portion of the bone, is composed of an infinite number of minute, almost microscopic cells, which are filled up by osseine, and bound thereby, as with a cement, into a solid mass.

The composition of bone, after the removal of adhering fat by boiling, is as follows:

Phosphate of lime,	63·1	per cent.
Carbonate of lime,	1·4	"
Phosphate of magnesia,	2·1	"
Other salts,	2·4	"
Osseine,	31·0	"
	100·0	

When submitted to heat in a closed vessel, to which air cannot gain access, the osseine is decomposed, evolving oily and ammoniacal products, which are, by suitable arrangements, collected and applied to many useful and economical purposes. In the retort remains the cellular structure of the bone in a most porous condition, each cell and pore being coated with a thin film of finely divided carbon, resulting from the decomposition of the organic osseine.

The purely chemical reasons why the porous animal charcoal should possess such extraordinary decolorizing and general absorptive properties, is a question I need not now enter into, but I shall do so fully in a forthcoming pamphlet.

II. The Decolorizing Properties of Animal Charcoal, and the Causes of its becoming Inactive.—It is well known to the refiner that his charcoal too soon loses the power of decolorizing his syrups, and the question arises, what is this owing to? It is *à priori* assumed that it is owing to the grains of coal becoming coated on the surface with the slimy albuminous and mucilaginous matters contained in the raw sugar, which destroy to a great extent its porosity. This is doubtlessly one cause, but the principal and by far the most serious cause is the presence of lime in the raw sugar, and which in a short time effectually chokes up the pores, and in the process of reburning cannot be removed, although the mucilaginous materials are destroyed.

III. The means of Restoring its Primary Powers of Absorption and Decolorization.—When the charcoal ceases to decolorize, it is usually washed with hot water to remove the syrup remaining therein, and then reburned in closed furnaces of various construction, the object of reburning being to carbonize the coloring matters extracted from

the syrups. This restores to some extent the decolorizing powers of the charcoal; but at each successive reburning the coal continues to lose its properties, and at last ceases altogether to act as a decolorizer, unless it be mixed after each reburning with a certain portion of new charcoal.

Another process, and one frequently adopted, is to destroy the organic matters by keeping the charcoal in water and allowing it to ferment for several days, draining off the water, and adding fresh water containing about $\frac{1}{4}$ to $\frac{1}{2}$ per cent. of hydrochloric acid. The little acetic acid formed, and the hydrochloric acid added, dissolve a small quantity of lime, and so far act beneficially. But the good effect is more than neutralized by the fact of the acids attacking the structure of the bone itself, namely, the phosphate of lime, thus rendering the coal friable, and consequently making much dust and waste.

Having referred to the two methods in common use of revivifying the decolorizing powers of charcoal, and alluded to their inutility and defects, I will describe a new method, as simple as it is ingenious, of rendering old and comparatively useless charcoal as good, and, indeed, better than new. Corenwinder, an eminent German chemist, has, by numerous experiments, established the following axiom, namely:

"That the decolorizing power of charcoal used in sugar refining is correlative to its power of absorbing lime."

In other words, the more the pores of the coal become choked up with lime, the less is its power of decolorizing. Now, to remove the obnoxious lime without attacking the structure of the bone itself, is a question which has occupied for many years the ingenious mind of my friend, Edward Beanes, C.E, F.C.S.

Mr. Beanes, who, by his chemical researches on the sugar plantations of Cuba, has enabled the planters not only to produce much finer qualities of sugar, but considerably to augment their produce, has recently patented a process of restoring to charcoal its primitive properties of decolorizing syrups. Mr. Beanes found that charcoal perfectly dry and hot absorbs dry hydrochloric gas with the greatest avidity and in enormous quantity. The gas combines with the lime and converts it into soluble chloride of calcium. After the charcoal has been treated with gas, a portion of untreated charcoal is mixed up with it; the uncombined gas remaining in the pores of the former is taken up by the latter, and the whole becomes neutral; the chloride of calcium is then washed out—requiring only a few hours—and the charcoal is afterwards burned in the usual way. It is then found that the decolorizing power of the charcoal is augmented at least 100 per cent.

The advantages of Mr. Beanes' process are as follows:

1st. It removes the whole of the lime and carbonate of lime from the pores without attacking the phosphate.

2d. It augments the decolorizing powers of the coal upwards of 100 per cent.

3d. It requires no expensive apparatus, and the process is almost costless, two saleable products being obtained nearly equal in value to the materials employed.

I have thus ventured to introduce Mr. Beanes' process to the notice of English refiners, not simply from feelings of personal friendship, but from the firm conviction that by its general adoption, he will confer as great a benefit on his own countrymen as he has already conferred upon the sugar manufacturers of Cuba.

Chemical Laboratory, 20, Great Marlborough Street, London, W.

For the Journal of the Franklin Institute.

Notes of Shipbuilding and the Construction of Machinery in New York and vicinity.

The Steamer Sacramento.—Hull built by Wm. H. Webb, New York. Machinery constructed by Novelty Iron Works. Superintendent of construction, Captain Francis Skiddy. Route of Service, San Francisco to Panama. Owners, Pacific Mail Steamship Company.

Hull.—Length on deck, 304 feet. Breadth of beam, 42 feet 6 inches. Depth of hold, 28 feet 6 inches. Number of decks, 3 full and orlops. Draft of water, 16 feet. Frames, molded, 16 inches, sided, 14 to 20 inches, apart at centres, 36 inches. Three water-tight bulkheads. Rig, brig. Tonnage, 26 7, O. M.

Engine.—Vertical beam. Diameter of cylinder, 100 inches. Length of stroke of piston, 12 feet. Is fitted with Sewell's condenser.

Boilers..—Four, tubular. No blowers to furnaces.

Water-wheels.—Diameter, 27 feet. Material, iron.

Remarks.—The *Sacramento* is built of white oak, chestnut, hacmetac, &c., the principal pieces being of live oak. She is filled in solid. Her fastenings are of copper and iron. She is strapped with iron straps diagonally and double laid, $4\frac{1}{2}$ by $\frac{7}{8}$-inches. Under her spar-deck are 280 knees, main-deck, 240, berth deck, 222, and orlops, 80, making in all 822 knees. Her water-ways are of yellow and white pine. This vessel embraces all the modern improvements for securing great strength, safety, and comfort. Proper ventilation is looked to in this vessel, the state rooms being very large, and lattice work secured in every position to insure a full and free circulation of the air in all the apartments.

The Steamer Euterpe.—Hull built by C. H. Mallory, Mystic, Connecticut. Machinery constructed by C. H. DeLamater, New York. Route of service, New York to Wilmington, N. C. Owner, C. H. Mallory.

Hull.—Length on deck, 176 feet 6 inches. Breadth of beam, 31 feet. Depth of hold, 10 feet 6 inches. Depth to spar-deck, 17 feet 6 inches. Number of decks, 2. Draft of water, 12 feet. Frames, molded, $12\frac{1}{2}$ inches, sided, 8 inches, apart at centres, 26 inches. No bulkheads. Rig, foretopsail schooner. Tonnage, 799, O. M.

Engines.—Vertical direct. Diameter of cylinders, 26 inches. Length of stroke of piston, 2 feet 6 inches.

Boilers.—One, tubular. Located in hold. Length, 16 feet 6 inches. Width, 13 feet. No blowers to furnaces.

Propeller.—Diameter, 9 feet 6 inches. Material, iron.

Remarks.—This vessel is of white oak, chestnut, and cedar, and is

square fastened with copper and iron. She has a full set of knees under both decks, and her floors are filled in solid. Her engine department is furnished with an independent steam fire and bilge pump, bilge injections, &c.

The Steamer Electra.—Hull built by Van Deusen Bros., New York. Machinery constructed by Etna Iron Works, New York. Route of service, New York to Providence, Rhode Island. Owners, Neptune Steamship Company.

Hull.—Length on deck, 245 feet. Breadth of beam, 40 feet. Depth of hold, 15 feet 6 inches. Draft of water, 10 feet. Frames, molded, 18 inches, sided, 7 inches, apart at centres, 24 inches. Four athwartship bulkheads. Rig, none. Tonnage, 1442 tons, O. M.

Engines.—Vertical direct. Diameter of cylinders, 44 inches. Length of stroke of piston, 3 feet.

Boilers.—Two, tubular. Located in hold. No blowers to furnaces.

Propeller.—Diameter, 13 feet. Material, cast iron.

REMARKS.—The floors of this vessel are filled in solid for 100 feet. She is of white oak, chestnut, and hacmetac, and square fastened with copper and treenails. Her bottom plank is of oak, 3½ inches thick. Wooden straps extend around the frame of the vessel. Her deck extends over the sides of the hull 9 feet and is sponsoned. The *Electra* is a fine vessel, built in the best manner, and gives satisfaction on her route of service. The steamer *Galatea*, of same line and constructed at the same time, is a sister ship.

The Steamer Ariadne.—Hull built and vessel owned by Charles H. Mallory, Mystic, Connecticut. Machinery constructed by C. H. DeLamater, New York. Route of service, New York to Wilmington, North Carolina.

Hull.—Length on deck, 183 feet. Breadth of beam, 34 feet. Depth of hold, 22 feet. Number of decks, 3. Draft of water 13 feet. Frames, molded, 12½ inches, sided, 10 inches, apart at centres, 26 inches. Rig, brigantine. Tonnage, 779 tons. O. M.

Engines.—Horizontal. Diameter of cylinders, 26 inches. Length of stroke of piston, 2 feet 6 inches.

Boiler.—One, tubular. Located in hold. Length, 16 feet. Width, 11 feet. No blowers to furnaces.

Propeller.—Diameter, 12 feet. Material, cast iron.

REMARKS.—This vessel is of white oak, chestnut, and cedar, and is square fastened with copper and treenails. Her floors are filled in solid. Under each beam beneath the two lower decks there are six knees, and under upper deck hanging knees every six feet, with lodging knees abreast of hatches. She is supplied with pumps, injections, &c., and is a well built steamer.

The Steamer Granada.—Hull built by Thomas Stack Williamsburgh, L. I. Machinery constructed by Fulton Iron Works, New York. Route of Service, New York to Charleston, S. C. Owners, Arthur Leary and others.

Hull.—Length on deck, 181 feet. Breadth of beam, 29 feet 10 inches. Depth of hold, 26 feet 3 inches. No of decks, 3. Draft of water, 16 feet. Frames, molded, 12½ inches, sided, 8 to 10 inches, apart at centres, 26 inches. Rig, brig. Tonnage, 762 tons, O. M.

Engine.—Vertical direct. Diameter of cylinder, 44 inches. Length of stroke of piston, 2 feet 9 inches.

Boilers.—Two, tubular. Located in hold. No blowers to furnaces.

Propeller.—Diameter, 11 feet. Material, cast iron.

Remarks.—This steamer is of white oak, chestnut, and hacmetac, and square fastened with copper and treenails. Has knees to each beam under deck. Bottom planks of white oak. Pilot house and officers' quarters on deck. The *Granada* is well constructed, well fitted, and will be a safe and useful vessel on her route of service. The steamer *Alhambra*, built at the same time, and owned by the same firm as the *Granada*, is a sister vessel.

The Steamer Cotopaxi.—Hull built by C. & R. Poillen, Williamsburgh, L. I. Machinery constructed by C. H. DeLamater, New York. Owners, Brazilian Government.

Hull.—Length on deck, 198 feet, 6 inches. Breadth of beam, 33 feet 6 inches. Depth of hold, 17 feet 6 inches. Draft of water, 13 feet. Frames, molded, 13 inches, sided, 8 and 9 inches, apart at centres, 26 inches. Rig, brigantine. Tonnage, 1054 tons, O. M.

Engine.—Vertical direct. Diameter of cylinders, 54 inches. Length of stroke of piston, 4 feet 4 inches.

Boilers.—Two, tubular. Located in hold. Use blowers to furnaces.

Propeller.—Diameter, 13 feet 4 inches. Material, cast iron.

Remarks.—This vessel is of white oak, hacmetac, &c, and is fastened in the securest manner with copper, treenails, &c. Around her frames iron straps diagonally and double laid, 4 by ⅝-inches, extend, adding to her strength. This vessel, owing to her admirable construction, speed, &c., was recently sold to the Emperor of Brazil, to be fitted and used as a gun-boat. That she will fulfil the sanguine expectations of both her builders and owners, not the least doubt exists.

E. M. B.

New York, May 25, 1865.

On the Use of Petroleum as Steam Fuel. By C. J. Richardson.

From the London Chemical News, No. 269.

As the patentee of the mode for burning petroleum as steam fuel, now being experimented upon at Woolwich Dockyard, permit me to reply to the article by Mr. Paul, which appeared in the *Chemical News*, of December 17 last. (See *Jour. Frank. Inst.*, vol. xlix, p. 130.)

The relative heating powers of petroleum and coal as depending upon their chemical composition is not the question; the ability of each to create steam is the real matter to be considered.

Petroleum as steam fuel can be very nearly fully utilized; it produces no ash, submits to mechanical management, and makes little or no smoke, does not require any strong draft or current of air like coal, which will not burn without it; and the consequence of which is, a very considerable portion of the fuel is lost as waste heat in the chimney.

In a late work by Mr. Wye Williams, one of our chief authorities on this subject, entitled "On the Steam Generating Power of Marine and Locomotive Boilers," he details three careful experiments as to the best form of boiler to obtain the greatest amount of heat from coal. He gives the temperature of the waste heat in the first experiment as 1060°; to the second, 760°; and the third, 635°—and this, be it observed, with the consumption of only 3½ cwt. of coal to each experiment. I should like to learn the temperature of the waste heat in the chimney of a furnace burning from twenty to thirty tons of coal per day. We know the current is so strong that it often carries up small coal and cinders along with it; that the heated gases often take fire by a spark from the furnace, and burn at the top of the funnel with a fierceness almost equaling the flame from a blast furnace. Is this flame or waste heat employed in creating steam? and how much is the coal utilized? In practice, the ratio of the heating power of petroleum and coal is about $=1{\cdot}4=0{\cdot}4$. We shall never learn the wicked waste we are making of our coal until petroleum supersedes it.

The American plan can be seen by inspecting the French patent; it was not likely to be successful; it does not follow that other more simple methods may not succeed.

My grate, which burns petroleum through a porous material, has has in every instance, when put under a boiler, proved petroleum to be full five times more powerful than coal for steam purposes—one ton doing as much as five tons of coal. If four tons out of five are saved for freight space, the price of the latter being 7*l.* per ton, the profit on every ton of petroleum would be 14*l.* 15s.,—the coal at 15s., the petroleum at 17*l.* per ton.

But a shipowner might not select the American crude at 17*l.*; he would take the Flintshire coal oil, quite as good for his purpose; this is only about 10*l.* per ton.

The average price of coal on a long voyage would be low at 2*l.* per ton. Taking these prices and freights at the reduced price of 5*l.* per ton, in a ship requiring 500 tons of coal, and using instead 100 tons of petroleum, would gain by the exchange 2000*l.* It would not be necessary to start with the full quantity of petroleum, it being more distributed about the earth than coal, obtainable at first cost in the oil countries.

As to the alleged advantage of the oil taking up less room than coal, no notice need be taken of it; a great deal more might be said of the advantage of a ship being able to go from port to port without turning aside for fuel.

Now, as to the highly dangerous, inflammable nature of petroleum, this is in a very great part fudge. If the oil were contained in cast iron cases securely closed, no vapor could escape; or if the small amount of spirit which produces the inflammable vapor was first extracted, the residue, the burning oil and heavy petroleum, would be no more dangerous than so much lard or spermaceti.

Use of Petroleum or Mineral Oil as Steam Fuel in place of Coal.
By B. H. Paul.

From the London Chemical News, No. 271.

This subject continues to excite so much interest among those connected with steam navigation, and the statements which have been made by those who propose by means of petroleum or coal oil to effect a reorganization of our naval and mercantile marine, are so totally irreconcilable with all known principles relating to the application of fuel, that it will not be superfluous to illustrate this fact by reference to the opinions expressed and to the arguments used by several of the speakers in a recent discussion of the subject at the United Service Institution. Such a course is the more admissible since many who appreciate the importance of any mode of improving or economizing the use of fuel, confess their inability to judge as to the merits of this project, and express themselves desirous of information.

The data which I have already referred to in this journal,* for the purpose of showing that the substitution of petroleum for coal as fuel is impracticable, are not disputed. On the contrary, they are adopted by those who advocate this change. But, at the same time, they urge that those data relate only to a theoretical consideration of the subject, and are therefore not to be taken as deciding the practical question as to the relative fuel value of petroleum and of coal. In this opinion I quite concur, but it must be remembered that no means of arriving at a practical solution of this question have yet been afforded. It was only from the want of such positive data, expressing results obtained with petroleum and with coal, as would enable an engineer, or any one else, to form an opinion as to the comparative values of these materials as fuel for steam vessels, that I was constrained to have recourse to the only accessible criterion by which an opinion could be formed as to the representations which have been made. The comparison of the utmost effects capable of being produced by petroleum and by coal under the most favorable conditions, is perfectly valid so far as it applies; but I must admit that it would have been far more satisfactory to have been able to base my opinion on the results of trustworthy experiments made with the object of ascertaining the actual duty obtained with the two materials, and I cannot refrain from expressing my surprise that statements so extraordinary as those I have referred to, should have been put forward ostensibly as the result of experiments made in the government dockyard, with the apparent authority they thus acquire, and without a vestige of practical evidence in support of them. Mr. Richardson has publicly declared that forty-two gallons of oil equal one ton of coal in steam-producing power. He admits that this requires proof, and he has promised that it shall be proved;† but as yet the proof has not been furnished, nor was any approach made towards it in the papers read at the United Service Institution, on the 16th inst. It rests, therefore, with the advocates for the use

* *Chemical News*, December 17, 1864, page 292.

† *Mining Journal*, December 24, 1864, page 890.

of petroleum to remove the cause of the objection they made to the comparison between that material and coal upon theoretical grounds.

But their chief argument in favor of petroleum is, that this material can be used as fuel so that its capability may be rendered effective to a much greater proportion than is possible in the case of coal. Here again we are without any evidence of a practical nature in support of this proposition. No doubt it is a well established fact that different kinds of fuel do not always admit of equal effects being produced in generating steam, although their heating capability or calorific power may be the same. It is upon this ground that the advocates of petroleum take their stand, and Mr. Richardson states that, while one-half of the coal consumed in a marine boiler furnace disappears and is lost as soot and smoke, the heating capability of petroleum is fully utilized.* If this were admitted, we should still be far from attaining that advantage from the use of petroleum in place of coal which Mr. Richardson represents by stating that one ton of petroleum equal five tons of coal; for, since the calorific power of petroleum is to that of coal as $1{\cdot}5:1$, it follows that by fully realizing the calorific power of petroleum and realizing only half that of coal, the practical effects of these materials would be in the ratio of $3:1$, not as $5:1$, which, upon the same supposition, would require the calorific power of petroleum to be $2{\cdot}5$ as compared with that of coal $= 1{\cdot}0$. There is, therefore, some error in this; but without attempting to ascertain in what it consists, it will be more useful to inquire how far there may be—in the absence of those special data which are so much needed—any means of instituting a practical comparison between coal and petroleum in regard to the possibility of using the latter more advantageously than coal as fuel in a marine boiler furnace.

It is well known that no kind of fuel is burnt under ordinary circumstances, so as to realize the whole of the heating effect it may be capable of producing. Therefore the true practicable comparison between different kinds of fuel as regards their value, consists in ascertaining not only what they respectively can do, but more especially what they really do. The actual work done by fuel depends partly upon its nature, partly also upon the kind of effect to be produced. When an intense degree of heat or very high temperature is required, as in smelting iron, the heating capability really utilized is not a tithe of that which is utilized when fuel is burnt for generating steam, and still less than that utilized when fuel is burnt in a common domestic grate.

But even in the generation of steam, different kinds of fuel give different results, and under the very unfavorable conditions which obtain in a marine boiler furnace, experience has shown that there is a great difference in the duty or effects produced by equal quantities of different coal possessing equal heating capabilities. Hence the recognised practical superiority of Welsh steam coal over the more bituminous kinds of coal represented by the North country coal.

Now, what is the difference between these two kinds of coal to which

* See *Times*, December 14, 1864, page 7.

their different value as steam fuel is referable? It is simply this, the Welsh coal is almost entirely fixed, approximating, in this respect, to pure carbon; it does not give out much combustible gas when heated, but it burns almost entirely within the furnace, and, unless the rate of combustion be very rapid, it burns completely, generating its full equivalent of heat, which is transferred through the medium of the combustion products to the water in the boilers. The amount of heat generated by the combustion of the best Welsh coal is equivalent to the production of nearly 15 lbs. of steam from water at 212° F. for each pound of the coal completely burnt. Of course, this duty is never realized in practice, because the water has to be heated to the boiling point, and because the whole of the heat generated cannot be transferred to the water in the boiler, great part of it escaping in the combustion products. But the approximation to that theoretical duty will be greater in proportion to the perfect combustion of the coal, and to the absence of soot or smoke production. For every pound of soot or smoke produced, the possibility of generating at least seven pounds of steam will be lost, and the duty of the coal will be proportionately reduced.

The calorific power of the best bituminous coal is not appreciably less than that of Welsh steam coal, but it contains from 30 to 40 per cent. of volatilizable substance, and consequently when heated combustible gas or vapor is evolved to that extent. This gas or vapor, amounting to something like 300 times the volume of the coal from which it is produced, mixes with the combustion products, and is thereby rendered less readily combustible. Under the influence of the draught, and by reason of its great bulk and mobility, it is drawn out of the furnace before it can be burnt, and, passing into the tubes of the boiler, the combustion is stopped partly by the cooling of the gas, and partly by the want of air, so that instead of generating its equivalent of heat it produces soot and smoke.

This action takes place to some extent with all coals, especially when it is burnt under the unfavorable conditions obtaining in a marine boiler furnace, and it was the disregard of this circumstance which vitiated the results of the long and costly experiments made some years ago by Dr. Lyon Playfair, with the view of ascertaining the relative value of different kinds of coal as fuel. But in regard to steam navigation, the relative values of different coals are determined by the degree to which this action takes place. The more a coal is capable of being burnt within the furnace, the better it is for that purpose. The greater the amount of volatilizable substance it contains, the less suitable it is, and the greater the extent to which production of soot and smoke is substituted for the production of heat. These being correlative results, it follows that the fitness of coal for steam navigation is inversely proportionate to the amount of volatilizable substance it contains. It is for this reason that while the duty obtained with Welsh coal sometimes exceeds 10 lbs. of steam per pound of coal burnt, that obtained with Newcastle coal is often as low as 6 or 7 lbs.

Applying this result of long experience to the case of petroleum as

compared with coal, the conclusion to which it leads is even more disadvantageous for the former than the comparison already made on the ground of calorific power and cost.* For petroleum is altogether volatilisable, and is, consequently, peculiarly liable to produce soot and smoke when burnt even slowly, and without any of those disadvantages to which it would be subject in the furnace of a marine boiler. Indeed, it appears to me that nothing can be more incompatible with the use of petroleum as fuel than the conditions which obtain in that case. No doubt it may be urged in answer to this that the introduction of a peculiar boiler is contemplated; but nothing need be said as to that contingency until the superiority of petroleum over coal shall have been satisfactorily made out.

The objection I have urged to the use of petroleum on the score of cost, has been answered by Capt. Selwyn, who suggests that the price of petroleum ought to be reduced if it came to be used as fuel, and that if it were not he believes a material almost identical with it may be obtained from coal at a lower cost, 9*l.* or 10*l.* per ton. So far as the price of petroleum is concerned, I am disposed to consider any anticipation of a reduction as being extremely delusive, and the lower cost of coal oil would still leave it at a great disadvantage as compared with coal.

But if Capt. Selwyn, before assuming the part of a protecting ægis to a deluded inventor, had applied to his own conceptions that simple axiom, that "a whole is greater than its part," he would probably have seen a little more clearly the value of the whole project of reorganization which it is proposed to carry out in relation to steam navigation. Thus, for instance, the very richest oil-yielding coal known—the Leeswood cannel—yields about one-third its weight of oil. In producing a ton of oil from three tons of this coal, a considerable quantity of combustible gas, capable of generating a large quantity of heat, is lost, and there remains greater part of the carbon of the coal in the state of coke, amounting to more than one ton. Both the gas and the coke are of value as fuel, so that the real fuel value of the oil from three tons of coal is, in fact, equal to the total fuel value of that quantity of coal *minus* the fuel value of the coke and gas. But according to the representations made in favor of substituting coal oil for coal as fuel, one ton of oil is to do the work of five tons of coal; so that, according to this view, the fraction of the heating power belonging to the three tons of coal will be equal to the heating power of five tons of coal!! This is equivalent to the proposition that part of three is equal to five, an absurdity so glaring that it is truly wonderful that it should have escaped recognition even by an inventor.

The signal misconception which characterises the views of those who advocate the substitution of petroleum for coal in steam navigation, was illustrated in an almost equal degree during the discussion following the papers read by Captain Selwyn and Mr. Richardson at the United Service Institution. Thus, for example, Sir Edward Belcher referred to the oxyhydrogen flames as proving the fuel value of hydro-

* See *Chemical News*, December 17, 1864, page 292.

gen to be much greater than that of carbon or of coal. Nothing could possibly be more irrelevant, and it can only be inferred that Sir Edward Belcher is not aware that the thermal efficacy of the oxyhydrogen flame is solely due to the fact that oxygen gas is used in the place of air for the combustion. This circumstance alone places the oxyhydrogen flame beyond the range of a practical consideration of the subject; but so far as a comparison can be instituted between hydrogen and carbon when burnt with oxygen, the fact is, that the thermal effect or temperature produced by carbon under that condition is far greater than that produced by an equal weight of hydrogen, these effects being in the ratio of about 10 : 7. When those substances are burnt in air, the difference in thermal effect is inappreciable. So far as the possible evaporative effect is concerned, the difference between petroleum and coal, in the amount of hydrogen they contain, is not so great as to have a very great influence; and since an increase in the amount of hydrogen in fuel is accompanied by increased liability to produce smoke and soot, it would, under existing circumstances, be rather a disadvantage than otherwise. Captain Selwyn's reference to the common fishtail gas burner used for illuminating purposes, and to the Bunsen burner, used in laboratories for heatings, as being illustrative of the different effects obtainable by burning combustible substances under different conditions, was equally infelicitous, and indicated an equal ignorance of the most rudimentary principles affecting the use of fuel; for in the flame of the fishtail burner, and in that of the Bunsen burner, the heating effects produced are equal for equal quantities of gas burnt, and the thermal effects or temperatures produced are probably little if at all different. Both these gentlemen appear to be very much "at sea" in their notions respecting fuel and its applications.

The view of this subject which was put forward in the above remarks will doubtless appear to many extremely trite and self-evident; but the fact that it is not so to every one interested in the use of fuel may perhaps be a sufficient excuse for stating it so fully, and the still more remarkable fact that some who have held such a view have been induced to abandon it, and to express themselves satisfied with the astonishing statements made as to the effects of petroleum when used as fuel, will show what strange results may be produced by vigorous assertion even of the most palpable absurdities. In fact, the whole of the arguments brought forward by those who contemplate effecting the entire reorganization of our navy, and of steam navigation, indicate a woeful deficiency of acquaintance with the subject, and well illustrate the proverbial danger of a "little knowledge."

There is, however, still room to hope that, by having recourse to that practical mode of deciding any question there may be in their minds as to the relative values of coal and petroleum, which I fully agree with them in thinking the only satisfactory test, and which is, unfortunately, a great desideratum in the present case, they will arrive at such a state of disillusion as will permit them to make a more useful application of their ingenuity.

The Steamship "City of New York."

The following is an abstract of a late voyage of this steamer from Liverpool, *via* Queenstown, to New York:

Wednesday, July 19, 1865.—Wind S. W.; Draft of water forward, 19 ft. 6 ins., aft, 20 ft. 10 ins.; 4·50 P. M. proceeded; 5·03 rock; 5·25 stopped; 6·28 took in tow by tender; 8·15 bell buoy; 8·25 tender left; ahead full speed.

Thursday, July 20.—Wind S. W. S. S. W.; 1·05 A. M. south stack; 4·15 slowed; 4·27 full speed; 9·25 Tinkar; 4·33 P. M. Roche's Point; 5·03 anchored; draft 19 ft. forward, 20 ft. 6 ins. aft; 7·15 proceeded; draft 19 ft. 3 ins. forward, 20 ft. 8 ins. aft; 7·38 passed Roche's Point.

Friday, July 21.—Wind W.; 135 miles; lat. 51·30, long. 13·16; 12·23 A. M. Fastnett; strong breeze and squally.

Saturday, July 22.—Wind N. W. W. N. W.; course N. 87 W.; 273 miles; lat. 51·42, long. 20·29; fresh breeze and cloudy.

Sunday, July 23.—Wind N. W. by W.; course S. 85 W.; 200 miles; lat. 51·20, long. 28·7; strong breeze and overcast; heavy head-sea.

Monday, July 24.—Wind W. W. N. W.; course S. 89 W.; 185 miles; lat. 51·15, long. 33·13; fresh gale and high sea.

Tuesday, July 24.—Wind S. W. W. N. W.; course S. 77 W.; 273 miles; lat. 50·14, long. 40·7; fresh breeze and variable.

Wednesday, July 26.—Wind W.; course S. 68 W.; 265 miles; lat. 48·36, long. 46·24; moderate and foggy.

Thursday, July 27.—Wind westerly; course S. 66 W,; 293 miles; lat. 46·38, long. 53·3; moderate and foggy; 12·20 P. M. delivered despatches at Cape Race.

Friday, July 28.—Wind southerly; course S. 57 W.; 299 miles; lat. 43·56, long. 58·58; fresh breeze and dense fog.

Saturday, July 29.—Wind S. W.; course S. 69 W.; 291 miles; lat. 41·51, long. 64·56; light breeze.

Sunday, July 30.—Course S. 75 W.; 302 miles; lat. 40·32, long. 71·24; light breeze; 10 P. M. Sandy Hook; 10·50 Quarantine.

Remarks.—Head winds retarded the vessel's progress very materially. Complete details of the construction of the *City of New York* will be found in the *Journal*, vol. xlvi, page 45. E. M. B.

On the Processes and Mechanical Appliances in the Manufacture of Polished Sheet Glass. By Mr. Richard Pilkington, Jr.

From Newton's London Journal of Arts, September, 1864.

The manufacture of British sheet glass was introduced into England about the year 1832, by Messrs. Chance Brothers, of Birmingham. Since then it has become generally used, having almost superseded crown glass, in consequence of the comparative ease of obtaining the large squares at present required for windows, and the absence of wave lines, by which the vision is so much distorted in crown glass. The average size of sheet glass is 40 inches by 30 inches, but, if required it can be made much larger, whilst with crown glass it is almost impossible to procure a square as large as 34 inches by 22 inches. Sheet glass, when used for windows, has generally a peculiar appear-

ance when viewed from the outside of a building, on account of the unevenness of its surface—an eyesore partially obviated by the improved method of flattening, but entirely removed when the glass is polished. When polished, it is known by the name of patent plate, to distinguish it from British plate. This polished sheet plate has a decided preference over British plate, being harder and more difficult to scratch, besides taking a higher polish. It is also cheaper.

The manufacture of polished sheet glass consists of the three following processes: 1st. Melting and blowing; 2d. Flattening; and 3d. Polishing.

1. *Melting and Blowing.*—Two furnaces are required, one for melting the materials or "frit," and the other for reheating the metal whilst blowing it into a cylindrical form. The melting furnace is a reverberatory furnace, arranged for maintaining a high temperature with great uniformity and freedom from dust or other impurities arising from the fuel. The furnace is fitted with pots, which are placed on a raised bed, extending the entire length of the furnace. The fire-grate also extends the entire length of the furnace, with the exception of a space of about 4 feet in length, and it is fed from the furnace. On each side of the fire-grate the pots are ranged, and a gathering or working hole is provided in the furnace wall for each pot. The air is supplied through an underground passage entering from the open air, and, by means of closely fitting doors, the draught is regulated with great nicety.

Formerly, it was considered necessary to use stone for the melting furnaces, but at the present time large bricks made of best fire-clay are preferred. A small fire is lighted upon the fire-grate and gradually increased, first to dry the furnace, and afterwards to bake it. Great care and attention are given to this operation, for upon it depends the duration of the furnace. After being baked, the furnace receives its number of pots, generally four or five on each side of the fire-grate, in all eight or ten pots.

The manufacture of these pots is a matter of special importance, and they are made of the very best Stourbridge fire-clay, which, when thoroughly tempered, is formed into rolls of about 1 ℔. weight each, and worked, layer upon layer, into a solid mass, free from cavities containing air, and making a pot of about 4 feet height inside, 5 feet diameter at top, and about 4½ feet diameter at bottom inside, weighing when dried about 25 cwt., and containing about 22 cwt. of melted metal. Great care is requisite to prevent any particles of foreign matter from getting into the clay, for if that were to happen, the pot would not last its time, but would most likely give way when first heated to the working temperature. The average duration of a pot is about eight weeks, and their estimated value about £9 each. After being made, a pot remains in the same room for a year, the temperature being maintained at 60° Fahrenheit; and it is then removed to a warmer room, where it remains in a temperature of 90° until it is wanted. When required for use, it is taken to the "pot-arch" to be baked, where the heat is gradually increased to that of the melting

furnace, to which it is conveyed, whilst red-hot, as quickly as possible, by means of a carriage or a crowbar on wheels, and placed on one side of the fire-grate. This operation is repeated until all the pots are fixed in the melting furnace. The furnace ends are now closed, with the exception of the fire-hole at each end. A small portion of "cullet" or broken glass is put into each pot, and when melted is ladled so as to run down over the interior surface of each pot, after which the heat is increased for a short time. The pots are thereby glazed, and are now ready to receive the material to be melted.

The quantity of raw material or "frit" allotted to each pot is filled into it in three or four charges, allowing a sufficient interval of time to elapse between each charge to insure the previous one being melted. About sixteen hours of intense heat are required to melt the entire quantity, during which time the fluid metal boils violently, and before it can be worked requires cooling, which takes about eight hours. Whilst cooling, the small bubbles of air arising from the boiling of the metal ascend and pass away, leaving the metal clear, excepting the surface, which is coated with impurities from the frit, from the roof of the furnace, and from the dust of the fuel, all of which must be removed before commencing work. Inside each pot, and floating upon the surface of the metal, is an annular ring made of fire-clay, 2 inches thick, having an internal diameter of 18 inches. This inner space of 18 inches diameter is cleaned, instead of the entire surface of the metal, thereby saving both time and material. The cleaning or skiming is performed by means of a light iron rod, chisel-pointed, which, being warmed, the metal adheres to it; and this process is repeated whenever any impurities are perceived upon the surface of the metal.

The surface of the melted metal being cleaned, the workman dips into it a blow-pipe, having previously warmed the nose end of the pipe. Withdrawing 2 or 3 lbs. of the metal, he allows it to cool to a dull red, and then dips the pipe again, collecting by degrees in this way a sufficient quantity to produce a given sized sheet of glass, which, on the average, would weigh about 20 lbs. Then, while cooling the pipe, he continually turns it round, drawing it towards himself, and in so doing forces the metal beyond the nose end of the pipe, by means of a forked rest, in which the pipe revolves, leaving as little metal as possible upon the pipe. The blower now takes the pipe and places the red-hot mass in a hollowed wooden block upon the ground, keeping the pipe in a horizontal position whilst revolving it, thereby producing a solid cylindrical mass of metal. During this process, his assistant allows a fine stream of cold water to run into the block from a sponge, to keep the wood from being burnt, and give a brilliant surface to the glass. He next raises the pipe to an angle of about 75°, and blows until he has produced a hollow pear-shaped mass, with its largest diameter the same as that of the finished cylinder. During this operation, his assistant keeps the block wet, and a second block is generally used when commencing the blowing.

The glass now requires reheating, which is done at a furnace built of ordinary brickwork, in an oblong form, its dimensions being deter-

mined by the number of blowers intended to work at it,—generally four, five, or six at each side. The ground at each side of this furnace is excavated to a depth of about 7 feet, a width of about 16 feet, and the same length as the furnace, and over each of these spaces four, five, or six wooden stages are erected at distances of about 2 feet apart. Having reheated the glass, the blower repeatedly blows to maintain the cylinder of equal diameter throughout, whilst lengthening it by swinging it backwards and forwards in the 2 feet space, and occasionally swinging it round over his head, until a cylindrical piece of glass is produced, about 11 inches diameter, and about 50 inches long, closed at one end, and having the blow-pipe attached to the other end. The blower first opens the closed end as follows: Enclosing as much air as possible within the cylinder, and stopping the mouth-piece of the pipe with his hand, he exposes the end of the cylinder to the heat of the furnace, which, whilst softening the glass at the end, expands the contained air to such an extent that a small hole is burst in the glass. This hole is flashed open by revolving the pipe quickly, and, when flashed, the end of the cylinder is withdrawn out of the furnace; and by keeping the pipe in a vertical position for a few seconds, the metal cools sufficiently to keep its shape. The cylinder is then placed upon a wooden trestle, and by touching with a piece of cold iron the pear-shaped neck near the pipe nose, a crack is formed, which is continued round the neck by gently striking the blow-pipe, and thus the pipe is released.

The cylinder has now one end of full diameter, but the other is contracted to about 3 inches diameter, and must therefore be cut off. This is accomplished as follows: The cylinder having become cold whilst remaining on the trestle, the workman collects a small portion of metal upon the end of an iron rod, and draws it into a thread of glass about $\frac{1}{8}$-inch diameter, by means of a pair of pincers. This thread he passes round the body of the cylinder, and after it has remained on a few moments, the pincers, dipped in cold water, are applied to the heated part; and the sudden contraction causes the end to fly off with a sharp report, leaving the cylinder about 45 inches long and 11 inches diameter.

2. *Flattening.*—To produce a flat sheet of glass from the cylinder thus obtained forms the second process of the manufacture. The flattening is accomplished as follows: The end of the cylinder that was flashed being slightly contracted in diameter, and the thickness of metal much reduced, it is first necessary to cut off about 2 inches length from that end; for this purpose the cylinder is supported in a vertical position, by means of a cradle over a small horizontal table; the bottom edge of the cylinder is introduced between the jaws of a small cutting instrument, and the movable jaw, carrying the cutting diamond, is pressed by a spring against the interior surface of the cylinder; then by gently pushing the instrument forwards round the cylinder, allowing it to run freely upon its wheels, the end of the cylinder is cut off perfectly true. The cylinder then requires splitting longitudinally, which is accomplished by placing it in a horizontal position in a wooden cradle; and a diamond fixed in the cleft of a stick is drawn along in-

side the cylinder from end to end, guided by the straight edge—a gentle pressure being exerted on the glass in opposite directions, at the diamond cut, to complete the splitting.

The cylinder is now taken to the flattening kiln, which consists of two furnaces built together,—the first for flattening, and the other for annealing; the former being maintained at a much higher temperature than the latter. A portion of the bottom of the flattening kiln, slightly larger than the largest sheet of glass to be flattened, is supported upon a carriage, which, with the flattened sheet, is made to travel into the annealing kiln, this plan being a very great improvement over the old method of pushing the flattened sheet whilst in a soft state. The movable bed is either of clay or stone, and by careful work is made as true as possible; upon this a sheet of glass is first flattened and left there to flatten others upon, in order to obtain sheet glass with as true a surface as possible. The split cylinder to be flattened is gradually introduced into the flattening kiln, and when sufficiently warmed is placed upon the glass bed with its split side uppermost. The heat soon softens it, so that, with a slight assistance from the workmen, it lies down nearly flat on the bed, and the sheet is afterwards rubbed as flat as possible with a piece of wood fixed to the end of an iron rod. The movable bed is now pushed forwards into the annealing kiln, and after placing another cylinder to warm, the workman removes the flattened sheet from the carriage by means of a tool like a fork, and places it upon a prepared part of the floor of the annealing kiln to stiffen previous to piling it. The carriage is now returned to the flattening kiln, and the flattening operation repeated, till the carriage again appears in the annealing kiln. The previously flattened sheet is first piled on its end against one side of the kiln, and then the last flattened sheet is removed off the carriage, and left to cool on the floor of the annealing kiln like the previous sheet. This flattening process is continued until the annealing kiln is filled, when it is closed up and allowed to cool, generally from 24 to 36 hours, the time being regulated by the thickness of the glass. On the completion of the cooling, the kiln is opened, and the sheets of glass are taken to the warehouse, where they are sorted to suit various purposes, a very large proportion being packed and sent away without undergoing any further process.

3. *Polishing.*—The sheets intended to be polished are now selected, and pass through the third process of manufacture, to produce polished sheet plate. Two processes are necessary for this purpose—smoothing and polishing.

Smoothing consists in working two sheets of glass, one upon the other, by hand, with emery and water between them; and as their surfaces become obscured, finer and finer emery is used, until the surfaces are smoothed free from all defects. The apparatus used consists of a wooden bench, one half of which is 6 inches higher than the other; upon the former is placed a slab of slate, about 1½ inch thick, larger than the sheet of glass, having as true a surface as possible. Upon this slab a sheet of glass is laid, with a piece of wet calico between the surfaces of the glass and the slab. By exerting a gentle pressure upon the

glass, the air is expelled from between them, and the sheet of glass is consequently held down upon the slab by the whole atmospheric pressure upon its surface, which holds it so firmly that when the sheets have to be raised from the slab, many are broken, even by experienced workmen. The wet calico is used in this case instead of plaster of Paris, for bedding the sheet of glass upon the table. In consequence of the close adhesion caused by the atmospheric pressure when the surfaces of the two sheets of glass get so true as to become closely in contact, it is impossible to work two large sheets, one upon the other, with the finest emeries, and it therefore becomes necessary to perform the latter portion of the rubbing process with a small piece of glass, say about 10 inches by 5 inches, until the process is completed. Both sides of the sheet of glass having been smoothed in this manner, and, after a careful examination, found free from defect, the sheet is then handed over to the polishing machine.

The perfection of the smoothing process is entirely dependent upon the purity of the emery, and the perfect uniformity of the grain in each successive quality employed; and consequently a very perfect process of cleansing and sorting the emery is requisite. The ordinary ground emery contains, besides numerous degrees of fineness of grain, many impurities which must be removed; and the good emery must also be accurately sorted into portions varying in size of grain from coarse to the finest. For every degree of fineness a separating vessel or cylinder is required; and, taking No. 1 as the coarsest quality, that cylinder is made the smallest in the series, No. 2 cylinder about twice the capacity of No. 1, and No. 3 twice the capacity of No. 2, and so on throughout the required number of cylinders. The emery sorting apparatus consists of the required number of cylinders fixed so that No. 1 cylinder is about 3 inches higher than No. 2, and No. 2 the same height above No. 3, and so on. The cylinders are made of copper, and inside each is fixed a copper funnel, long enough to reach within 3 or 4 inches of the bottom of the cylinder; and in the bottom of the cylinder is a hole, closed by a wooden plug or valve of about 3 or 4 inches diameter, which is held up by a rod and spring balance. The action of the apparatus is as follows: A supply of water being maintained by the cistern, a constant stream is delivered, by means of a tap, into the funnel of No. 1 cylinder. The water descends through this funnel to the bottom, and ascends through the annular space to the top of the cylinder, whence it is conveyed by a spout to the funnel of No. 2 cylinder, ascending in the annular space of No. 2, and passing by a spout to No. 3 funnel. This is repeated as often as there are cylinders; and from the last and largest cylinder the overflow is carried to a drain. When the stream of water is running through all the cylinders and also passing away at the overflow, the powdered emery to be cleansed and sorted is sprinkled into the funnel of No. 1 cylinder, and this is continued until enough has been fed to fill up to within $\frac{1}{2}$-inch of the bottom of the funnel. No. 1 being the smallest cylinder, the current of water through it will be the fastest, and the grains of emery left behind in this cylinder will consequently be the coarsest. The feeding of the

emery is then stopped for a short time, and the stream allowed to continue until the water is running quite clear into the funnel of No. 2 cylinder. A valve at the bottom of No. 1 cylinder is now opened, allowing the emery and water to fall into a vessel placed beneath to receive it; and as soon as the stream of water is again running through all the cylinders, and passing away at the overflow, more emery is again sprinkled into No. 1 funnel. The succeeding cylinders are emptied in the same way, as they respectively become filled with the finer sorts of emery. The beauty of this process is the simplicity of the apparatus required, and the certainty of always obtaining an exact repetition of the several degrees of fineness in the respective cylinders. It will be observed, that, in consequence of the cylinders increasing successively in capacity, the current of water ascending in the annular spaces decreases in velocity in the same proportion; consequently the emery deposited in each successive cylinder increases in fineness over that deposited in the previous one.

For the final process of polishing the sheets of glass after smoothing, the machine used is the same as that described at a previous meeting for polishing plate glass. The polishing benches have two bars, carrying the polishing blocks, and working lengthways, backwards and forwards, over the table on which the sheet of glass is laid, which is made to travel alternately from side to side transvesely to the bars. The polishing blocks are worked at about sixty double strokes per minute, and the bars carrying them are supported upon rollers at a height of 6 or 8 inches above the table. The moving table is worked similarly to the table of a planing machine, moving one way quicker than the other, by a reversing motion, similar to that of a planing machine bed.

It is generally considered that, to obtain a good polished surface, the polishing blocks should not pass twice in succession over the same surface. Upon the moving table are fastened slabs, made of a wooden frame, covered with slates, upon which the sheets of glass to be polished are bedded in plaster of Paris. After one side has been polished, the glass is taken up and relaid, and the other side polished. The polishing blocks are about 5 inches square, covered with felt, and weighted with about 84 lbs. each. The red liquor used is polishing is red oxide of iron, obtained by burning sulphate of iron in a reverberatory furnace to a dark red when cold, and it is then ground in water to the finest grain possible. The cutting grain of this material is about the hardest and finest that can be produced, and well worth examination by the microscope.

Mr. Pilkington exhibited a series of specimens from the St. Helen's Crown Sheet and Plate Glass Works, illustrating the several stages of the manufacture, and the materials employed.

The chairman observed that the members had had an opportunity, on the occasion of the Liverpool meeting, of seeing the manufacture of plate glass at the Ravenhead Works, and a paper on the subject had been read on that occasion; and the present paper gave a corresponding description of the manufacture of polished sheet glass.

Mr. P. Rigby observed that polished sheet glass was a very superior

article to the crown glass of which it had taken the place, and required more care in the final polishing process, in order to get both sides of the glass finished to the same degree of polish. Much depended upon the correct separation of the emery powder into proper gradations of fineness, which was effected by the successive cylinders in the emery washing apparatus being made in correctly-adjusted progression, as regarded their size. Great care was also needed in feeding the emery powder into the first funnel, so as not to go on feeding too long, otherwise some of the coarser particles would get carried over by the current of water into the next cylinder, along with the finer sorts. The time of polishing the sheets of glass was generally required, in his own experience at Messrs. Chance's works, to be longer for the side first polished; because when the plate was turned over for polishing the second side, the first surface became slightly dulled by being laid in the plaster; and he inquired whether, in the specimens exhibited of polished glass, the time of polishing had been equal for both sides, or longer for the first side.

Mr. Pilkington replied, that it took about nine hours on an average to polish each side of a sheet of glass, but there was no fixed time for the process, the polishing being continued until the surface of the glass was brought up to the requisite brightness; and he had not found that it afterwards became dulled at all by being laid in the plaster for polishing the other side, the plaster having no sensible effect on the brightness of the surface. Even in what was called the rough state, however, before smoothing or polishing, sheet glass was quite equal in appearance to ordinary crown glass; while the finest and thinnest sort of polished glass of which a sample was shown, was that made for the use of photographers, and for framing fine engravings. The emery sorting apparatus was found in practice to divide the different sizes of emery with extreme accuracy into the respective cylinders, as was proved by examining with a microscope the several degrees of fineness.

Mr. J. E. Clift inquired whether the rubbers had to be moved at intervals during the polishing process, in order to examine the surface of the glass.

Mr. Pilkington replied, that was not necessary, as the rubber traveled far enough at each stroke to expose the whole surface to view; and the workman examined the degree of polish of the surface, by holding a lighted candle near it while the glass was still lying on the slab of the machine. The process was stopped as soon as the glass appeared sufficiently polished.

Mr. F. J. Bramwell observed, that if it were the fact that the surface of the glass became at all dulled by being laid in plaster, and if it were attempted to compensate for this by polishing the first side longer than the second, the result must be that both sides would be defective in polishing, the second side not being finished to a greater degree of polish than the first side would have after lying in the plaster. The smoothing and polishing processes here employed were indeed identical with those in the manufacture of plate glass; but the latter required a preliminary process of grinding, on account of the unevenness of its

surface on leaving the annealing oven, whereas the blown sheet glass had its surface sufficiently even to allow of its being laid at once on the smoothing machine, without having undergone grinding. The emery sorting apparatus was the same that was used in plate glass machinery, and he did not think a more perfect plan could be devised for separating the several degrees of fineness. The principle was as simple as possible, the different sized particles being accurately sorted according to the velocity of the current of water in the successive cylinders, just in the same manner as a river discharging itself into a lake, deposited the heavier portions of its detritus at the entrance, and carried the lighter matters further out into the body of the lake. A similar method had formerly been employed in the preparation of beaver for the manufacture of hats, the hairs being separated from the beaver by a current of wind just sufficient to float the beaver; this accordingly deposited the hairs at a near point, but carried the beaver to a greater distance. In grinding the emery, the old plan had been to grind it dry under edge runners, and as there was no provision for removing the particles as fast as they were ground, the consequence had been that some portions were overground, and impeded the grinding action of the machine upon the portions that still required grinding. Now, however, by grinding the emery wet, with a stream of water constantly carrying off the particles as soon as they were ground, the machine was kept continually cleared, and was enabled to grind in two days as much emery as it had previously ground in six. The principle of the stream of water was the same as that of the air blast used in mill-stones to remove the flour from between them, and in the American rice-husking machines for blowing away the husk of rice grains as soon as it was broken up fine enough to be so removed.

The Chairman inquired whether any improved mode of laying and lifting the plates of glass on the machines had been devised, in order to diminish the risk of breaking the glass. He thought there seemed room for improvement in that respect, for at present the loss by breakage of the glass in handling was very great.

Mr. Pilkington was not aware of any improvement having been made in that respect, though it was certainly much needed.

Mr. E. A. Cowper observed, that for smoothing the sheets of glass, instead of the process being performed by hand, as described in the paper, a machine was employed at Messrs. Chance's works, in which the smoothing action was produced by a link motion, like the parallel motion of beam engines, the upper sheet of glass not working right round upon the lower, but passing over it in a curvilinear course, with a figure of 8 movement. The melting furnace employed appeared to be the ordinary form of furnace used for glass melting, previous to the introduction of Mr. Siemen's regenerative gas furnace. In the construction of the old furnace, one practical difficulty arose from the "tears" or droppings of dirt from the brickwork forming the roof of the furnace, which dropped into the glass melting pots, and damaged the glass; this was now obviated by setting the lower rows of bricks each a little in advance of the upper, so as to present a slight step in-

side the furnace, which prevented the "tears" from dropping, and caused them to run down the sides of the furnace instead. The use of a current of air for separating fine substances, to which reference had been made, was also adopted in the process of grinding sulphur for vulcanizing purposes.

Mr. P. Rigby remarked, that the smoothing machine used at Messrs. Chance's works had been adopted for giving the smoothness of polished plate glass to sheet glass, as that was now required for many purposes, and particularly by photographers; but hand smoothing never made the surface quite so smooth and uniform as was done by the machine.

Pro. Mech. Eng. Soc.

New Green Pigment.

From the London Chemical News, No. 281.

Under the name of "Green Cinnabar," Vogel describes a new color which is prepared in the following way: Prussian blue is dissolved in oxalic acid; chromate of potash is added to this solution, which is then precipitated with acetate of lead. The precipitate, well washed, dried, and levigated gives a beautiful green powder. By varying the proportions of the three solutions, various shades of green may be procured. Chloride of barium or nitrate of bismuth may be used in place of sugar of lead.—*Chem. Central Blatt.* [Another mode of preparing this color will be found at page 182, vol. ix, *Chem. News.*]

The Strength of Cast Iron Water Pipes.

From the London Mechanics' Magazine, November, 1864.

Before the introduction of cast iron, water pipes were made in England of fig tree wood, and straight pipes, from twelve to twenty feet in length, were bored out of this material. Such pipes are now very scarce here, but we have seen many in use for even rather large mining pumps in eastern Europe. Wooden pipes can be made from one and a half to eight inches in the bore, which is generally one-third of the diameter of the pipe. The joints are, of course, upon the spigot and socket plan. Cast iron has now superseded wood for this purpose almost everywhere, although the introduction of such a strange material as tarred pasteboard is now being attempted for water pipes. The insides of cast iron pipes are generally varnished, or are sometimes covered with hydraulic cement in order to protect them from oxidation.

It will be seen that the strength of the metal depends upon the pressure of the water and the diameter of the pipe. The thickness of a cast iron water pipe is never so great as to bring into play those peculiar conditions of tensions which exist, for instance, in the cylinders of hydraulic presses or of ordnance. A water pipe is simply strained like the comparatively thin cylindrical shell of a boiler, or of a steam pipe. A cylinder undergoing an interior pressure, which tends to either increase its diameter or to burst it, while the section of the metal is of equal thickness throughout, is a sufficiently simple

case. The interior pressure tends to split the pipe longitudinally in a plane passing through the axis of the cylinder. The pressure exercised on any given length of piping is clearly equal to the product of the pressure per any given unity of surface, say per square inch, into the area of a rectangle, the height of which is the interior diameter of the pipe, while its length or base is equal to the length of the pipe itself. The total pressure is thus the fluid pressure multiplied by the interior diameter and by the length of the pipe. The surface of metal which resists this tension is equal to the external diameter *minus* the internal diameter multiplied by the length of the pipe, or twice the thickness of metal multiplied by the length. There will, therefore, be equilibrium between the force which tends to produce rupture and the resistance if the product of the coefficient of rupture of the metal, with the difference of the inside and outside diameters, be equal to the internal tension. This would be the bursting tension, which is, for cast iron, about 16,500 pounds per square inch. The working tension is usually one-sixth of this, or 2,750 pounds per square inch, while the proof tension, or the pressure at which the pipes ought to be tested, is twice the working tension. It is clear on reflection that the resistance of pipes of internal tension is quite independent of their length. As the length increases, so does the metal which has to resist the increased pressure due to additional length also increase in the same direction. Mr. Fairbairn has given the results of two experiments on leaden pipes, which show that the resistance of pipes to internal tension is independent of length. He has also made similar experiments in tubes of plate riveted together, and of different lengths. The results were very irregular, and did not demonstrate much beyond the fact that rupture always took place at the riveting.

Such is, of course, the theoretical strength of water pipes; but there is a great difference between a calculation of theoretical strength and the necessary regard to the complicated requirements of practice. When all the different points influencing the behaviour of even such an apparently simple thing as a water pipe are taken into consideration, some excuse is found for existing empiricism. On the other hand, the really practical man is he who neither neglects, nor is ignorant of the sublime teachings of science on the one hand, nor common sense requirements on the other. Amongst the practical conditions which are not to be met here by calculation, may be reckoned accidents in fitting in pipes, and the consequent external strength they ought to have in order to resist without fracture any sudden blow or accidental pressure from the outside. Another very important reason why such pipes should have a strength and thickness beyond that which would be due to the pressure of the water, is their liability to shocks caused by sudden stoppages of the current of water, and producing effects similar to those in the machine called Montgolfier's hydraulic ram. The danger is all the greater, as the speed is greater, and inferior granular cast iron often sweats under this action, even if the metal does not entirely give way. These dangers are necessarily diminished if the cocks and valves are so arranged as to close gradually. Another very important

effect on the strength of a pipe would be any inequality in its shape, equivalent to a serious departure from a true hollow cylinder. Fluid pressure, acting in all directions, continually strives to produce a perfectly cylindrical pipe, and thus the material of a tube which is not perfectly cylindrical, is injuriously strained in an unexpected way by this action. For these reasons, in fixing the strength of gas and water pipes, a constant thickness is added to that which is determined, in order to merely resist the interior pressure. Of very great influence is, of course, the quality of the metal, as the range in quality of cast irons is very great. The mode of casting is also of very great effect. A cast iron bar cast vertically is often nearly one-third as strong again as a bar cast horizontally, and pipes cast vertically are much superior to those cast horizontally.

For many years the engineers of the water works of Paris used the formula: $E = 0^{m}\cdot00238 n\, D'' + 0\ \cdot0085$; in which E is the thickness of the pipe, n is the number of atmospheres of pressure per square metre, which has to be supported by the tube, D'' is the inside diameter, the numbers being given in metres. This would correspond to an ultimate resistance of 2,170,000 kilogrammes per square metre. Morin states that the improvement of late years in the quality of cast iron, and the plan of casting the pipes vertically have allowed these thicknesses to be somewhat reduced. The present formula is: $E = 0^{m}\cdot0016 n\, D'' + 0^{m}\cdot0080$, in which the resistance to rupture of the cast iron is taken at higher value of 3,000,000 kilogrammes, while the pressure is taken as equal to 10 atmospheres. The formula is thus brought to: $E = 0^{m}\cdot016\, D + 0^{m}\cdot008$. In the few cases where great strength is required, with a larger diameter than usual, it is probable that the principle of shrinking rings on the outside of cylinders intended to withstand great pressures, might be occasionally adopted in the case of large water pipes, at least to a limited extent. Careful cooling from the inside, as with Rodman's guns, would also produce a stronger tube.

The best and most solid joint for any pipe is a flange joint, and the only reason for its non-adoption in any particular case is, that other joints—such as the common socket joint—are cheaper. Of course, the flange joint, however good and strong, is but little used in any great length of tubes, on account of its great expense. With a long length of pipes, compensation joints have to be adopted, in order to take up the effects of expansion and contraction of the metal, caused through the alterations of temperature. The expansion of cast iron is 0·0000111 for every degree Centigrade of heat, and the difference of the lowest temperature in winter to the highest in summer being nearly 50° C., this amount of expansion has to be multiplied fifty times. A joint of this kind is generally put down at every three hundred feet of length. The most disastrous effect, however, on any pipe is that of frost, and no winter passes by without our hearing complaints on this matter, and without noticing letters from indignant correspondents in our own columns and those of the daily papers. The bursting effect of frost is probably practically irresistible. A bomb-shell, if filled with water, the hole for the fuze being closed by a screw, is easily burst by the

expansion of the water inside while freezing. Gunpowder exerts a pressure of some 30,000 lbs. per square inch, so that the force of expansion of the freezing water is at least equal to this amount. For reasons which we have not yet heard sufficiently explained, water may be at freezing point, but if kept flowing will not freeze. The slight internal friction of the water itself, and more especially its friction against the sides of the pipe, probably develop a certain amount of heat. At the same time, the mere fact of the flow keeps the pipes clear, and can be supposed to drive any ice, which might be even on the brink of formation, out of the pipe. It is probable that in our own comparatively mild climate, the freezing and consequent bursting of pipes in winter are oftener due to the bad nature of the material than to temperature alone. The water is taken up by capillary attraction into the porous sides, and having soaked itself in, it expands with irresistible force within the spongy mass, driving it asunder. We here see the very great necessity for testing the pipes by hydraulic pressure, more especially if they be cast horizontally. The theoretical strength and the practical strength required are easily calculated, but no reckoning could take into account the effects of bad material or bad casting. As we have observed, the proof tension should be twice the working tension, which is itself generally made one-sixth of the ultimate strength of the pipe, or that tension at which it should burst.

In the designing of a series of water mains, there is a great field for the display of science and the production of economy of material and working power. Sudden bends and knee pipes should be entirely avoided, and curved pipes should be used with as large a curvature as possible. Sudden changes in the diameter are also to be prevented, and the passage from one diameter to another should take place as gradually as possible. The gain is of a double kind. In the first place, obstructions to the flow cause shocks, which either require great strength in the pipes themselves, or end by breaking them up. In the next place, such obstructions cause great losses in useful effect, which have to be paid for in some way—in the extra engine power, for instance. There can be no doubt, again, that there is one point with regard to water pipes which is still to a great extent ignored by most practical hydraulicians. We mean as to the effect of the state of the surface on the flow, and also as to the influence of the diameter. A large number of experiments which have been lately made in France would seem to point to this, and we lately took occasion to allude to their importance.

On the Supposed Nature of Air prior to the Discovery of Oxygen.

By George F. Rodwell, F.C.S.

Continued from vol. xlix, page 406.

From the London Chemical News, No. 272.

In Obs. 16 "Of Charcoal or Burnt Vegetables," Hooke propounds his celebrated theory of combustion, a most philosophical and ingenious theory, and far in advance of the chemical knowledge of the day.

From very ancient times fire was believed to be an element more

divine than air, water, and earth, and to occupy a place above them. We find this theory in the most ancient Vedas, in the Zend Avesta, and in the writings of Sanchoniatho; indeed, we know that fire was the divinity of the Zoroastrians, and first invoked among the deities of the ancient Hindus, was Agni, the god of light and fire. Fire was universally believed to be an element till the time of Bacon, and almost universally for many years afterwards. Bacon,* in his investigation of the nature of heat, denies that it is elemental, and states his belief that it is "merely compounded of the conjunction of heat and light in any body;" heat, he elsewhere affirms, is a violent motion of the smallest particles of bodies, and heat can produce light, hence he completely destroyed the elemental nature of fire. Hooke went much further than this, for his theory affirmed:

1. That the air is the "universal dissolvent of all sulphureous bodies."
2. That the dissolution does not commence until the body to be dissolved has been heated to a certain temperature.
3. That the process of dissolution generates that which we call *fire*.
4. That the process of dissolution is performed with such intense violence that it agitates the smallest particles of the combustible matter, with sufficient rapidity to generate "the action or pulse of light."
5. That the solution of sulphureous bodies is made by "a substance inherent and mixed with the air, which is like, if not the very same, with that which is fixed in saltpetre."
6. That in the process of dissolution, a part of the combustible body is turned into air, and caused to move with it.
7. That in the process of dissolution, a part of the combustible body is not turned into air, but is carried up by the motion of the hot air, and when the heat ceases, descends again, and this part is a certain kind of salt found in soot.
8. That in the process of dissolution, certain bodies capable of being dissolved are carried upwards, and do not suffer dissolution, because the motion of the surrounding air does not allow them to remain sufficiently long in a heat competent to cause them to be acted upon by the air, and this is the combustible part of soot.
9. That there are parts of the combustible body which cannot be dissolved by the air, and are not sufficiently light to be carried upwards by the motion of the hot air, and this constitutes the ash of burnt bodies.
10. That "the dissolving parts of the air are but few," they soon become satiated, and the combustible body then ceases to be acted upon, until it is supplied with a fresh quantity of air; but in saltpetre the dissolving particles abound in great quantity; hence this body is able, when melted, to rapidly dissolve a large quantity of a combustible body.
11. That, as with liquid solvents, if we repeatedly add fresh quantities of a weak solvent, the body to be dissolved disappears as quickly as if a strong solvent be added all at once, so if we apply fresh quantities

* "Nov. Org.," Book 2, Aph. 20.

of air repeatedly, as by bellows, to a body undergoing combustion, it suffers solution as quickly as when it is placed in melted nitre.

12. That there is no such thing as an "element of fire," for the "shining transient body, which we call flame, is nothing else but a mixture of air and the combustible volatile parts of any body, which parts the encompassing air does dissolve or work upon."

This theory had been worked out by Hooke several years earlier, and was well supported by experimental facts; it is much to be regretted that he does not give any of the experiments, neither has he, in any future publication, enlarged or developed the theory, although he states that he has here "only time to hint an hypothesis, which, if God permit me life and opportunity, I may elsewhere prosecute, improve, and publish." Assuredly if he had adduced experiments in support of his assertions, the theory of four elements would now have been annihilated; but this earliest amongst the physical conceptions of the human intellect, was not yet destined to receive its death-blow; that which had dwelt so long in the human mind, had taken such a deep root therein, had endured uninjured, through the greatest changes of intellectual development, the greatest changes in the tone and mode of thought, had seen the downfall of old systems of philosophy, and the rise of new ones, could not so easily be displaced from the minds of men. Many years must pass; experiments must be accumulated; chemistry must free itself from empiricism and become a science; the Phlogistic theory must arise, and be vanquished by Lavoisier, before that change can take place.

In the 58th observation of the "Micrographia" Hooke treats "of a new property of the air." It is constantly observed, he writes, that the sun and moon, when near the horizon, have their images distorted, and assume a red color; moreover, trees and other objects are sometimes observed to possess an unsteady appearance at sunset; these effects he attributes to the "inflection or multiplicate refraction of those rays of light within the body of the atmosphere." That the refractive power diminishes with its rarefaction, Hooke proved by viewing an object through a hollow glass sphere, containing much rarefied air, and then admitting air; the object was viewed through an aperture placed in front of the sphere, of such a size that every part of the object was just included in the field of view; on now admitting air to the interior of the sphere, a part only of the object was visible.

We know that the air is less dense the further it is from the surface of the earth, from the fact that the mercury column sinks in a barometer as we ascend a mountain; and, he continues, the law regulating the descent of the mercury may be illustrated by "a means which somewhile since I thought of and used, for the finding by what degrees the air passes from such a state of density to such a degree of rarity." He next details a number of experiments—made with precisely the same apparatus as that employed by Boyle—which prove conclusively that the volume of air varies inversely as the pressure to which the air is submitted.

It is remarkable that Hooke does not mention Boyle's name in connexion with the law, although in the "Defence against Linus," published more than two years previously, Boyle (as we have seen in a former paper) gives a number of experiments clearly proving the law; moreover, he had described his experiments at several meetings of the Royal Society in the presence of Hooke. We cannot imagine that Hooke wished to give Boyle less than his due, for he constantly mentions suggestions which he received from him, and always speaks of him in the highest terms. In the preface of the "Micrographia" he speaks of "the most illustrious Mr. Boyle, whom it becomes me to mention with all honor, not only as my particular patron, but as the patron of philosophy itself." Again, he speaks of "the incomparable Mr. Boyle." It is also remarkable that Boyle does not mention Hooke's name in connexion with the law, for the former is always most ready to acknowledge the discoveries and inventions of others. It is impossible to say who first verified the law; at all events, Boyle was the first to suggest that the experiments should be made, and to describe a method for making them. Hooke speaks of his own experiments as *confirming* the law, not as giving rise to it; indeed, both he and Boyle attribute the idea that "the pressures and expansions are in reciprocal proportions" to a Mr. Richard Townley. We must remember that at the time of the discovery of the law, the air was the only gaseous body known, and a law which had been proved to apply to one body, would obviously be considered of a less importance than one which applied to a whole class of bodies. It is to this that we must attribute the fact that no trouble was taken to ascertain the true history of the law by those writers who lived at the time of its discovery.

The history of the law, as far as I have been able to trace it, seems to be the following:

1660.—Boyle, in his "Physico-Mechanical Experiments," suggests a method for determining the relation of the density of air to the height of the column of mercury which it supports.

Townley, after reading Boyle's suggestion, makes some experiments on the subject, which induce him to propound the theory that "the pressures and expansions are in reciprocal proportions."

Hooke, not having heard of Townley's theory, makes some experiments, but without finding that "the pressures and expansions are in reciprocal proportions."

Mr. Croune and Lord Brouncker make some experiments on the subject.

1661, (August 2.)—Hooke, having heard of Townley's theory, makes some further experiments by a different method, which confirm it.

September 11.—Croune gives an account of his experiments on the subject before the Royal Society.

Boyle, at the same meeting of the Society, describes some experiments previously made, which confirm the theory.

1662.—Boyle in his "Defence against Linus," publishes a detailed account of the experiments described before the Royal Society in the

previous year, and affirms that "an accurate experiment of this nature . . . has not yet been made (that I know) by any man."

1665.—Hooke publishes in detail the experiments made on August 2, 1661.

1676.—Mariotte, in his "Essai sur la Nature de l'Air," publishes some experiments made by himself and a M. Hubin, which confirm the law.

I must still adhere to the opinion expressed in a former paper, that the law which affirms that the volume of a gas varies inversely as the pressure to which the gas is submitted, is rightly "the law of Boyle."

Hooke, not only by his writings, but by inventing and improving many philosophical instruments, eminently benefited experimental science. Now that the old philosophy was to be expelled from the minds of men, now that Nature was no longer to be interrogated by the unaided senses, it was necessary that there should be instruments to assist the inquirer. Hooke was the very man that was wanted at the time; a good mathematician, possessing admirable inventive faculty, and a patient experimenter. He was a greater mechanical genius than Boyle, but I will not say a more ardent experimenter. Both were worthy to put in practice the tenets of the new philosophy; both were true types of the Baconian philosopher; their names will never disappear from the annals of science, will never cease to be reverenced by all true students of Nature.

(To be continued.)

The Coal Mines of the World.

From the Journal of the Society of Arts, No. 657.

M. A. Burat, in a work entitled *Situation de l'Industrie Houllière en* 1864, gives the following as the statistics of the extent of known coal fields and their annual production:

	Extent in hectares, (1 hectare being equal 2·471 acres.)	Tons.
British Isles,	1,570,000	86,000,000
France,	350,000	10,000,000
Belgium,	150,000	10,000,000
Prussia and Saxony,	300,000	12,000,000
Austria and Bohemia,	120,000	2,500,000
Spain,	150,000	400,000
North America,	30,000,000	20,000,000
Total,	32,640,000	140,900,000

As regards France, the coal basin of the Loire, which is only 25,000 hectares in extent, furnishes three-tenths of the whole of the coal raised in the country.

Improvement in the Giffard Injector. By M. Turck.

As this instrument was originally constructed, the cylinder which receives the steam, its nozzle, and the needle which occupies its axis, slid together in the enveloping jacket when it was necessary to change the opening of the annular orifice by which the feed-water mixes with the steam. This arrangement requires two stuffing boxes. M. Turck removes these boxes, and renders the cylinder, nozzle, and needles fixed, and avoids the contact of the cold water with the wall of the steam-nozzle, by interposing between the cylinder which receives the steam and the jacket a metallic piece surrounding the cylinder and its nozzle. This envelope alone is movable, and by its longitudinal motion closes or opens the annular space by which the feed-water enters. The Committee of the *Society for the Encouragement of National Industry* approve of the change and publish the specification and drawing.

Coloration of Glass.

M. Pelouze having observed that the glasses of commerce were colored yellow by carbon, sulphur, silicon, boron, phosphorus, aluminum, and even by hydrogen, was lead to make a series of experiments for the purpose of ascertaining the cause of the identity of the results with such different reagents. The conclusions which he has reached, and which his experiments place beyond doubt, have a very considerable importance in reference to the possible perfection of our manufactures of glass. In fact, his first conclusion is that "all the glasses of commerce contain sulphates." These salts (sulphates of soda, potassa, or lime) render the glass more or less alterable by atmospheric agency, and come into the glass from two sources, either directly from the use of these sulphates as a flux, or from the presence of the sulphate of soda as an impurity in the commercial carbonate. The effect of their existence may be seen by examining many of the panes of glass in our windows, which have been for some years exposed to the air, when the surface of the glass will be found to be corroded and partially opaque like ground glass, and by examination under a magnifier will be found to be covered with crystals. M. Pelouze found these sulphates present from one to three per cent. in all the commercial glasses, window, plate, table, bottle and Bohemian glass: he also found two per cent. of sulphate of soda in a glass from Pompeii. The coloration is now easily explained, the reagents named above reduce the sulphates and produce an alkaline sulphuret which has the property of giving the yellow color.

M. Pelouze proved his proposition by showing, first, that when the glass materials were carefully purified from sulphates, no color was produced by carbon, hydrogen, boron, silicon, phosphorus, or aluminium; and, secondly, that an alkaline sulphuret added to the pure materials produced the color.—*Acad. Sciences of Paris.*

A Comparison of some of the Meteorological Phenomena of JULY, 1865, *with those of* JULY, 1864, *and of the same month for* FIFTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	July, 1865.	July, 1864.	July, for 15 years.
Thermometer—Highest—degree, . .	97·00°	94·00°	100·50°
" date, . . .	7th.	31st.	21st, 1854.
Warmest day—mean,	87·33	86·17	91·30
" " date,	28th.	31st.	21st, 1854.
Lowest—degree, . .	63·00	60·00	53·00
" date, . . .	14th.	22d.	2, 3, '62; 3, '57
Coldest day—mean, .	70·00	66·33	59·70
" " date, .	14th.	25th.	3d, 1857.
Mean daily oscillation,	12·13	15·73	15·62
" " range, .	4·44	3·81	3·81
Means at 7 A. M., . .	74·76	72·39	73·76
" 2 P. M., . .	83·44	83·48	83·43
" 9 P. M., . .	76·66	76·97	76·27
" for the month,	78·29	77·61	77·82
Barometer—Highest—inches, . . .	30·141 ins.	30·066 ins.	30·212 ins.
" date, ...	31st.	18th.	5th, 1859.
Greatest mean daily press.,	30·078	30·038	30·197
" date, ...	31st.	18th.	5th, 1859.
Lowest—inches, . . .	29·537	29·518	29·443
" date, ...	17th.	2d.	19th, 1851.
Least mean daily press., .	29·598	29·585	29·462
" date, . . .	17th.	2d.	30th, 1856.
Mean daily range, . . .	0·089	0·114	0·094
Means at 7 A. M., . . .	29·766	29·784	29·834
" 2 P. M., . . .	29·752	29·747	29·805
" 9 P. M., . . .	29·771	29·783	29·822
" for the month, .	29·763	29·771	29·820
Force of Vapor—Greatest—inches, .	0·917 in.	0·860 in.	0·983 in.
" date, . .	25th.	2d.	26th, 1854.
Least—inches, . .	·342	·255	·255
" date, . . .	10th.	22d.	22d, 1864.
Means at 7 A. M., .	·614	·540	·609
" 2 P. M., .	·605	·537	·604
" 9 P. M., .	·635	·592	·635
" for the month,	·618	·556	·616
Relative Humidity—Greatest—per ct.,	90·0 per ct.	97·0 per ct.	97·0 per ct.
" date, .	25th.	25th.	often.
Least—per ct., .	37·0	27·0	26·0
" date, . .	9th.	23d.	23d, 1856.
Means at 7 A. M.,	70·2	67·2	72·3
" 2 P. M.,	53·3	46·6	52·9
" 9 P. M.,	68·2	63·2	69·9
" for the month,	63·8	59·0	65·0
Clouds—Number of clear days,* . .	10	8	7
" cloudy days, . .	21	23	24
Means of sky cov'd at 7 A. M.,	57·4 per ct.	62·9 per ct.	59·3 per ct.
" " " 2 P. M.,	62·6	58·7	59·4
" " " 9 P. M.,	40·6	35·8	41·5
" " for the month,	53·5	52·4	53·4
Rain—Amount, ...	2·135 ins.	3·742 ins.	3·696 ins.
No. of days on which rain fell, . . .	9	8	10·9
Prevailing Winds—Times in 1000,	s88° 42′ w·273	s 75°5′ w·263	s63°47 w·161

* Sky, one-third or less covered at the hours of observation.

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CIVIL ENGINEERING.

On the Wear and Tear of Steam Boilers. By FREDERICK ARTHUR PAGET, Esq., C.E.

(Continued from page 102.)

From the Journal of the Society of Arts, No. 649.

4. *The Chemical and Physico-chemical Effects of the Feed-water.*

The wear and tear of a boiler which occurs in the form of corrosion, properly so called, may be divided into two principal kinds: (1.) Internal, and (2.) external. The progress of both is necessarily intensified by the mere effects of temperature; each, however, has its strongly marked, distinct character—not merely as to position, but also as to origin and results.

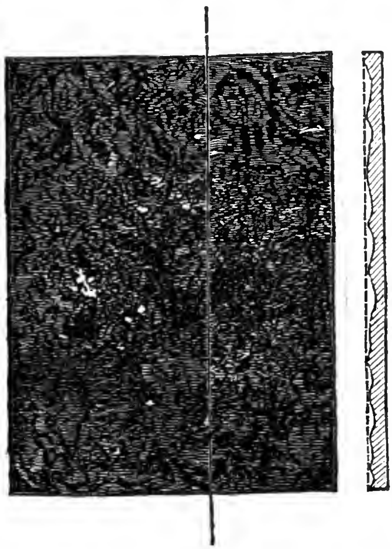
A steam boiler is in the position of a vessel into which large volumes of water are continually forced; while the heat applied, driving off all volatilizable matter, leaves behind a concentrated solution with a chemical character dependant on that of unvolatilizable matters in the feed-water. The specific gravity of the substances found in the water naturally causes them to sink towards the bottom, at which part the solution is generally more concentrated, however much it may be stirred up by the ebullition. Mr. J. R. Napier lately stated that a piece of zinc "about four feet long, by three inches broad, by three-sixteenths thick, placed in a marine boiler for three weeks" to a depth of 18 inches in the water, showed a corrosion which rapidly decreased "up to the highest part, which, in the steam, appeared to be little affected."* This accounts for the fact that all boilers, even those

* Institution of Engineers in Scotland, Session 1864–65.

internally fired, like locomotive boilers, have their plates most affected towards the bottom, and that internal corrosion always shows itself to a greater extent below the water line. The *bouilleur* of the form of boiler known as the French boiler, is also generally more affected than any other part. To resist this sort of slow action, it is clear that the more the bulk of metal the better, and it is for this reason that the bottom plates of most marine boilers are made thicker, while these same plates in locomotive boilers have to be often renewed. Any chemical or physico-chemical action of the kind is, of course, intensified by temperature, and this is one of the causes why externally fired boilers give way most a little in front of the furnace. But the plates above the water line also get more or less corroded, and not merely with the usual character of rusting, but in that peculiar form known as pitting, which generally shows itself much more strongly marked below the water line.

The presence of a concentrated solution of an acid or alkaline character, kept at a high temperature for years in contact with iron plates, would be sufficient to account for much corrosion. But the internal corrosion of steam boilers has many features of such a mysterious character, that no accredited explanation of its attendant phenomena has yet been put forward. In the first place, plates thus attacked show a number of irregular holes like a pock-marked human face, or like the small craters seen on the moon's surface. (See fig. 4.) The writer has also sometimes observed two or three little irregular excavations like this in a plate otherwise showing a large surface quite intact. Sometimes the plate is most pitted round a projecting bolt; at others, one plate will be perfectly sound, while that riveted to it will be almost eaten away, both having been the same time at work, and under, of course, apparently exactly similar conditions. With locomotive boilers this pitting has been ascribed to galvanic action between the brass tubes and the iron plates. But it is notoriously well known to locomotive superintendents, that boilers with iron tubes are often worse pitted than those which have run the same distance with brass tubes. Besides, all iron boilers, with or without brass, whether used for stationary, locomotive, or marine purposes, are subject to pitting.

Fig 4.



(The internal surface of a plate of an old wrought iron boiler, showing one-quarter of the full size the ordinary appearance of pitting.)

An explanation which seems to meet all the circumstances of the case is the following: Mr. Mallet, in a report addressed to the British Association some years ago, showed that wrought iron and steel (blister steel probably) "consist of two or more different chemical compounds, coherent and interlaced, of which one is electro-negative to the other." In fact, ordinary wrought iron, being also welded up from differently worked scrap, is far from being an electro-homogeneous body. In a boiler, the hot water, more or less saturated with chemical compounds, is the exciting liquid, and the electro-positive portions of the plates are thus quickly removed to a greater or less depth. This explanation meets most of the known circumstances with respect to pitting; it even, in a great measure, explains how plates above the level of the water, especially in marine boilers, get very rapidly corroded in portions, while another part of perhaps the same plate is scarcely affected. The concentrated water in a marine boiler is known to be generally acid. "Of all the salts contained in sea water," says Faraday,* "the chloride of magnesium is that which acts most powerfully" on the plates. He shows that a cubic foot of sea water contains 3·28 oz. of salt; and, at the same time, points to the danger of voltaic action in a boiler through the contact of copper and iron. In a smaller degree, the contact of cast with wrought iron, or between the different makes of wrought iron in the same plate, or between contiguous plates, acts in the same way. It is not improbable that some hydrochloric acid is present in the steam of marine boilers. "Mr. J. C. Forster† has tested some of the condensed steam from the safety valve casing, and from the cylinder-jacket of the Lancefield, and found both decidedly acid."‡ With an exciting liquid in the condensed steam, it is thus explicable how the plates of marine boilers often get corroded in a most capricious manner; while, at the same time, the current of steam would create a certain amount of friction on the oxide, clearing it away to act on the fresh surface.

The crucial test of this explanation of pitting would be the observation of the absence of the phenomenon from plates of an electro-homogeneous character. This homogeneity could only be expected from fused metal such as cast steel. Accordingly, while the writer was in Vienna a short time ago, he was assured by Mr. Haswell, the manager of the Staatsbahn Locomotive Works, that some locomotives made of cast steel plates in 1859, for the Austrian Staatsbahn, had been working ever since without showing signs of pitting, though, under similar conditions, iron plates had severely suffered in this way. Pitting may thus be fairly defined as a form of corrosion localized to particular spots by voltaic action. It is also probably aggravated through the motion of the plate by chemical action, and the expansions and con-

* Fifth Report of the Committee of the House of Commons concerning the Holyhead Roads, p. 194.

† Institution of Engineers in Scotland, 1864–65. Introductory address by Mr. J. R. Napier.

‡ When a solution of chloride of magnesium is evaporated nearly to dryness, the salt and the water are decomposed, magnesia and free hydrochloric acid being formed; or $MgCl + HO = MgO + HCl$.

tractions through alterations of temperature. All boilers are most pitted near the inlet for the feed-water, and with inside cylinder locomotive boilers there is generally more pitting at the smoke-box end —no doubt caused by the more or less racking action on these plates. A state of corrosion at particular spots would probably be kept up to a greater intensity by the incrustation being mechanically thrown off. With a quicker voltaic action, caused by any usual intensity of the exciting liquid, the sides of the cavities in the plates would be sharper and less rounded off, as in the case of the boiler fed with mineral water from ironstone workings, which exploded last year at Aberaman, South Wales. (See Fig. 5.)

The fact that pitting occurs in marine boilers when distilled water from surface condensers is used, does not affect this explanation. Water distilled in this way, from whatever cause, after repeated boiling, is stated to carry the salinometer even higher than sea water, thus proving it is not pure.* In the next, there is the absence of incrustation, which to some extent always protects the plates of boilers from the chemical action of its contents. In this way the mechanical buckling of the plates,—directly and indirectly causing the furrows we have spoken of—by continually clearing particular lines of surface from incrustation and oxide, reduces these particular spots, with respect to corrosion, to the condition of the plates of a boiler fed with water which deposits no incrustation. Corrosion will also act more rapidly at a furrow through mere increase and renewal of surface. To resist that form of internal corrosion specially known under the name of pitting, a maximum of electro-homogeneity is evidently required in all the component parts of the boiler.

Fig. 5.

(From a photograph of surface of corroded plate cut from one of the two boilers that exploded on Wednesday, February 17th, 1864, at Aberaman Iron Works, Aberdare. The corrosion was internal, and in some parts the plate was not more than one-eighth thick. Thirteen persons were killed, and many others seriously injured.)

While the action of internal corrosion, often very equally corrugating the plates over a large surface, as a rule scarcely, at any time only gradually, affects their mechanical strength, external corrosion,

* Institution of Mechanical Engineers, 1863. Discussion on Mr. James Jacks' paper "On the Effects of Surface Condensers on Steam Boilers."

being localized to particular spots, is of a much more dangerous character. The one is gradual and easily perceptible, while the other is rapid and insiduous in its progress. Apart from accidental circumstances affecting the brickwork on which a stationary boiler is erected, or the outside of the bottoms of marine boilers, it is clear that external corrosion can only occur through leakage. When leakage takes place through a crack in the plate caused by mechanical action, or at a hole burnt out by heat, the effects of leakage are only secondary results, due to a primary cause which of itself may cause the stoppage of the steam generator. But a leakage at a joint may in itself gradually cause the destruction of a boiler. Here we see another reason that the character of a boiler, not merely as to ultimate strength, but also as to wear and tear, intimately depends upon the form of its joints. It is often noticeable that very good lap-joints, even when tested under hydraulic pressure up to only 50 per cent. above the working load, sweat more or less. The tendency of the internal pressure to form a correct circle bears indirectly on these joints, causing them to open more or less, and to leak in spite of the caulking. Mr. Robert Galloway, C.E., who, as an engineer surveyor of long standing of the Board of Trade, has probably made more than three thousand careful inspections of marine boilers, states that he has often noticed a furrow or channel on the outside of a joint, running parallel to the outside overlap for some distance, and evidently caused by leakage. Along the water line, condensed water will act on the joints, while below it the concentrated contents of the boiler will come into chemical action. A leakage in a marine boiler often eats away a plate within a year. In some cases a jet of hot water from a leakage has a frictional action; in fact, even with such an incorrodible and hard substance as glass, an effect like this has been perceived, and a slight leakage continued during several days, sometimes produces a noticeable furrow on a glass gauge tube. With sulphurous fuel, a powerful chemical action will come into play on the plates. One volume of water takes up about thirty volumes of sulphurous acid gas; and these sulphurous fumes of the fuel coming into contact with the water from a leakage, will be more or less absorbed. An acid solution like this must quickly eat away the plate. It is certain that a leakage acts much quicker on a boiler fired with sulphurous fuel than on one fired with wood. M. G. Adolphe Hirn has observed a plate nearly seven-eighths thick, to be pierced, in the course of time, as with a drill, by means of a little jet which struck it after passing through a current of hot coal smoke.*

Legislative Enactments.

No stronger proof can be adduced of the empirical state of existing knowledge of the management of boilers than that afforded by a consideration of their average duration. While some marine boilers last only about three years, there are carefully worked land boilers which have lasted as long as thirty. Captain Tyler, R. E., estimates the average duration of a locomotive boiler at from five to twenty years.

* Bulletin de la Société Industrielle de Mulhouse, 1861, p. 558.

Perhaps the average duration of a marine boiler may be reckoned at from five to seven years; that of a locomotive boiler at from eight to nine years; that of a stationary boiler at from eighteen to twenty years; all being supposed to be fairly worked under ordinary conditions.

It is clear that, subjected as a steam boiler is to so many destructive influences, the precise effects of which can scarcely be yet very accurately known, the working tension should be only one-eighth of the ultimate bursting strength. But when boilers, as is too often the case in England, are bought by the weight; when cheaply paid labor is employed in their management; when inspection of the progress of the wear and tear necessarily happening even with good boilers and good attendance, is procrastinated for the sake of gain, there is then a suit of expense versus risk, in which parsimony too often gains the day. At any rate, a number of painful accidents in all parts of the world have, at different times, pointed to the fact that every man picked at hap-hazard cannot be safely trusted with steam power. In fact, there is probably no civilized country in which the legislature has not more or less interfered in the management of steam boilers. In the States of America, the frequency of boiler explosions has in some localities produced a more despotic interference than perhaps anywhere else. In the city of New York, boilers are under the supervision of the municipal police; they are tested periodically, and as a result many are condemned every year. By an enactment of Congress, applicable to all the States,* steam passenger vessels are subjected to government inspection. The 13th section of this Act shows a very acute perception of the real cause of a boiler explosion, "which," it states, "shall be taken as full *primâ facie* evidence" of negligence on the part of the owner, upon whom is thus put the onus of disproof. The law of Louisiana† is particularly severe, requiring the application of a hydraulic test threefold that of the working pressure. Of course, there is a great distinction between enacting a law and putting it into practical execution, and it is probable that laws like these could only be carried out by organized bodies of police, like those on the Continent. In France, in 1810, 1825, 1828, 1829, 1830, 1843, and lastly on the 25th of January, 1865, as many different regulations have been issued with respect to steam boilers of all kinds. Beginning by requiring that every boiler, even of wrought iron, should be submitted to a hydraulic test of five times the working pressure, this has been successively lowered down to a threefold pressure in 1843, and lastly to a twofold pressure by the Imperial decree of this year.‡ The previous law fixed the minimum thickness of the plates—a regulation which undoubtedly did much injury to boiler making in France. The old Prussian regulation of the 6th of May, 1838, also fixed the thick-

* Session of Congress, July 7, 1838.

† Baltimore American, 1835.

‡ Décret concernant la Fabrication et l'Establissement des Machines à Vapeur. 25 Janvier, 1865.

nesses of the plates, but did not require any hydraulic test. By the *Regulativ** of the 31st of August, 1861, this was completely altered. The construction of the boiler was left entirely in the hands of the maker, but stationary boilers had to withstand a threefold, and locomotive boilers a twofold hydraulic pressure. In the same way as with the present French law, the test had to be repeated after any considerable repairs. On the 5th of March, 1863, a ministerial decree reduced the testing pressure for old locomotive boilers down to $1\frac{1}{2}$ of the working pressure; and another *Circular Erlass*, published on the 1st of December, 1864, reduced the test for all kinds of boilers down to twice the working load. There is now no material difference between the French and the Prussian regulations respecting boilers; and it may be expected that those continental States, such as Russia, Switzerland, and Spain, which have more or less copied the old French law of 1843, will also adopt the present alterations. There is also some talk about altering the present Austrian law,† which determines the thickness of the plates, but only demands a double pressure test. The Belgian *réglement*‡ also requires double the working pressure for common boilers, but only $1\frac{1}{2}$ for tubular boilers. According to Article 31, the test must be annually applied to locomotive, portable, and marine boilers, as also after all considerable repairs. There does not seem to be any general law in Italy, but in the special acts authorizing railway companies, similar requirements to the French regulations are laid down, and government commissioners see that they are carried out. Each of the smaller German States also has its law more or less like that of France and Prussia. Mecklenberg-Strelitz§ requires that common boilers be proved to three, and tubular boilers to twice the working pressure, to be renewed every fourth year, and every time that the boiler is repaired or altered; Saxony|| that cylindrical boilers be tried to twice the working pressure, and tubular boilers to a pressure three atmospheres above it. Bavaria¶ now requires double the working power pressure for new, and one and a half for old boilers; while both Hanover and Brunswick each have a somewhat similar regulation.** The French law, and indeed most of the others, require two safety valves, and many are extremely minute in their directions with respect to glass gauges, steam gauges, and other fittings. In Great Britain there are no express legislative enactments with respect to boilers beyond those stated in two clauses of the Merchant Shipping Act,†† according to which (1) one safety valve in every boiler of a

* Düsseldorfer Zeitung. 24 ste September, 1861.

† Reichs-Gesetz-Blatt fuer das Kaiserthum Oesterreich, 1854, page 229.

‡ Ministère des Travaux Publics, Machines à Vapeur. Réglement. Donné à Læken le 21 Avril, 1864.

§ Grossherzoglich Mecklenburg-Strelitzer Offizieller Anzeiger, No. 11, 1863.

|| Gesetzliche Verordnungen, die Anlegung von Dampkesseln betreffend. Dresden Meinhold und Sœhne, 1865.

¶ Regierungs-Blatt fuer das Kœnigreich Bayern, 22 Februar, 1865.

** Gesetz-Sammlung fuer das Kœnigreich Hannover, 1863.

†† Merchant Shipping Act, 27th June, 1854, Nos. 289 and 298.

vessel carrying passengers shall be placed beyond the control of the engine-driver; and (2) any overloading of this valve is made punishable by a fine of not more than £100, "in addition to any other liabilities" which may be incurred by such act. The boilers of all vessels carrying passengers before clearing out of port are subjected to a careful inspection by an engineer surveyor of the Board of Trade, who can require the boiler to be tested in the usual way to twice the working pressure; and if he thinks fit, he can, as the result of such an examination, place the option before the shipowner of either lowering the working pressure or renewing the boiler. Armed with such powers, the government surveyor is also responsible for any explosion which may directly occur through wear and tear. When an explosion takes place on a passenger railway, one of the Board of Trade inspectors of railways examines the fragments and reports upon the accident to the government board, who communicate it to the railway board. The reports are then printed, in order to be presented to Parliament, and this is the extent to which the British government can interfere in these cases. As with other railway accidents, however, the Board of Trade inspector is examined as a witness in any action for damages against the railway company. All other boilers in the United Kingdom are worked without any government or municipal interference whatsoever. Within late years, however, private companies (the first of which was organized by Mr. Fairbairn, of Manchester), have been formed for the prevention of boiler explosions. In return for a small annual fee, or for a small annual insurance premium, the boilers of any subscriber or insurer are periodically inspected, and, if required, tested by skilled engineers. There can be no doubt that these companies have already prevented a great amount of loss and disaster.

It may thus be said that there are three distinct plans for the general management of steam boilers: 1. There is the continental plan; 2. the free English and American mode; 3. what may be termed the Manchester system. The continental mode consists in a strict supervision, sometimes ruled by formulæ, of the original construction, and there its action may be said for the most part to end. It does not and cannot, without periodical inspections, take into account the effects of wear and tear. It may even be doubted whether the old French law, for instance, did not do more harm than good as regards construction. The official formula, according to which were calculated the thicknesses of the plates, founded as it was upon the assumptions that a cylindrical boiler formed an exact circle, and that a plate, however thick, conducted the same amount of heat to the water, was obviously incorrect. What may be termed the ordinary English and American plan throws the onus of proof of the negligence of the owner on those damaged by an explosion. This system is subject, besides other difficulties, to all the objections that exist against the trial of scientific questions by a jury not composed of experts and unaided by scientific witnesses. The continual occurrence of explosions in those cities and States of America in which boilers are used without any supervision by the authorities, and their undue occurrence in England with boilers that are not

subjected to systematic inspection, sufficiently prove that steam boilers cannot be worked at hap-hazard. On the other hand, the system of organized inspection by the English boiler companies, and the similar system, according to which the passenger vessels are inspected by government officers, have given universal satisfaction. A proper estimate of the value of the Manchester and Board of Trade system, compared with the continental and with the *laisser faire* plans, could only be well based on numerous statistics. Unfortunately, such do not appear to have been formed. It is stated,* however, that in an average of 277 boilers, there were two explosions in the French Department of the Haut-Rhin within ten years; and, from 1856 to 1861, or within five years, there were only two explosions in an average of 1371 boilers, under the care of the Manchester Association. About four explosions occur annually amongst the 6500 locomotives of the United Kingdom; three have already taken place this year. In an average of 600 passenger vessels inspected under the Steam Shipping Acts, only three explosions occurred since 1846–47 in Great Britain, viz: one at Lowestoff in the *Tonning;* another at Southampton in the *Parana;* and a third at Dublin. These last results speak very highly for the care and abilities of the engineer surveyors of the Marine Department; and the continental system is thus clearly inferior to that adopted by the Board of Trade. What is evidently wanted is, that the system of skilled periodical inspection should spread over the kingdom. To a certain extent this is taking place, but this progress is slow and needs some stimulus, while it is doubtful whether, in out-of-the-way districts, the mere expense of inspection is not a great bar. What seems to be needed is, that in the event of a fatal explosion, the coroner of the district should be enabled to write to the Home Office for scientific assistance in arriving at the originating cause. The Secretary of State might then call upon any competent engineer for a report on the matter, when he could be examined as a witness before the jury. The mere knowledge that any explosion would be strictly investigated by an expert, might, in many cases, be sufficient to counterbalance the too prevalent tendency to prefer risk to expense.

The Hydraulic Test.

Although, as we have seen, the application of a well known amount of hydraulic pressure is in such general use for the determination of the strength of a boiler, there are, nevertheless, few points in engineering about the real value of which there is so much dispute. Everybody seems to have a different opinion on the matter. Some say that the hydraulic test is the only means of determining the strength of a boiler; others that it is a very injurious and useless measure. As to its amount, some recommend one and a half, many twice, some thrice, and a few even four times the working pressure. While numerous engineers advise its application to old boilers, others have strong objections to its use in this way. Whether the force-pump be really the best apparatus for its application, is, with other questions, also placed in

* Bulletin de la Société Industrielle de Mulhouse, 1861, page 525.

doubt. The truth is, that while, on the one hand, like other tests, it may be abused and wrongly applied, on the other, its value may also be exaggerated.

The best practical proof of its necessity for new boilers is afforded by the fact that explosions have occurred the first time steam has been got up—such as that at the Atlas Works, Manchester, in 1858. Unless every plate be separately tested up to proof load, it is impossible to be certain whether one of them is not defective. This function is clearly much better performed by the hydraulic test. Then, as to its application to old boilers, much can be learned during internal examination, but it is not always possible to tell the remaining thickness of the plates by this means, nor their deterioration through the heat. It is often said that a successful resistance to the hydraulic test is no proof that the boiler might not have been burst by a few pounds more; and that it may so suffer as to perhaps afterwards burst with less pressure of steam. But this is no more true than it is true of a girder, for instance, which has withstood, without permanent deflection, its proof load. In every case it is necessary that its effects on the boiler should be exactly ascertained. In fact, the real test consists in this examination, and the proof pressure is only a means to this end. The boiler should, if possible, be subjected to a careful internal and external examination. With locomotives this can only be accomplished by taking out the tubes; with ordinary land boilers it can only be done by removing the brickwork. In fact, it may be said that a steam boiler is never absolutely safe which cannot be easily examined—more especially from the inside. But by gauging the flue tubes, the combustion chambers, the flat surfaces, and even the barrels, it may be ascertained very nearly whether the limits of elasticity of the material have been exceeded—whether therefore the pressure has additionally injured a boiler which was near rupture already. It is often very plausibly observed that there is great danger in testing a boiler, which cannot be examined internally to double, or even to only one and a half the working pressure. It is said that the test may strain the boiler without its showing any outward indication. It is certainly just possible that such a case might happen. A locomotive boiler, which had been tested with 196 lbs. pressure, the water being at 162° Fahr., in September, 1860, but had not been examined internally, burst on the 1st of April, 1861,* under only 120 lbs. of steam. The boiler gave way at the smoke box ring of the barrel, and, as usual, from a furrow or crack running close to and parallel with the inside overlap of the longitudinal joint. It is difficult to believe that if this ring, as well as the others, had been gauged after stripping the lagging from the outside, as is done by the engineers of the Manchester Boiler Association, it would not have shown a permanent increase of diameter or some bulging under the extra pressure. If, in addition to a neglect of careful measurements before and after the application of the pressure, this test is carried very high, then the whole operation may undoubtedly be a cause of that which it is intended to prevent. According to

* Board of Trade Report. 1861. Part 4.

the Prussian law, every new locomotive boiler had to be re-tested to double the working pressure after running 8000 Prussian miles, and afterwards for each 5400 miles. These measures, while they did not entirely prevent explosions, greatly injured the boilers, by straining the stay bolts, and by the resulting excessive caulking required to make the joints tight. On the other hand, the absolute security afforded by drawing the tubes can, under the present mode of construction, be only obtained at the expense of perhaps 300 tubes, costing from 25*s.* to 27*s.* each, besides some injury to the tube plates.

Whatever may be said against the hydraulic test, the best argument in its favor is its very general adoption. New government boilers in the United States must be tried to a pressure two-thirds greater than the working pressure; the same measure being carried out with the 3000 boilers in the city of New York. Mr. Anderson, C.E., of Woolwich,* directs his subordinates to use a test of at least double the working pressure for the boilers in the royal gun factories. Mr. Muntz, of Birmingham, has publicly stated that he has for years adopted an annual hydraulic test, "considering it a duty he owes to his workmen." The Eastern Counties, the South Eastern, the Lancashire and Yorkshire, the Caledonian, the North British, the Edinburgh and Glasgow, and the London and South Western Railway companies employ the hydraulic test for both new and old boilers, using generally double the working pressure. The London and North Western are stated to have used it for only new boilers—at any rate until recently. The Great Northern and the Great Western Railway companies do not use it, and it is accordingly on these lines that the greater number of explosions take place. Practical experience thus proves that, though there is just a chance of the test failing to detect a weak boiler when it cannot be examined internally, the danger is greater in not using the hydraulic test at all. Mr. Beattie, of the London and South Western, strips the lagging every two years, and applies a pressure of 190 lbs., the working pressure being 125 lbs. Mr. Fletcher, of the Manchester Boiler Association, employs double the intended working pressure for new, and from $1\frac{1}{2}$ to $1\frac{3}{4}$ the working pressure with old boilers. The most commonly used test is thus double the working pressure for old boilers, with a diminution according to circumstances as they get old.

An objectionable plan in measuring the pressure applied, and, for several reasons, one likely to lead into error, is estimating it from the load on the safety valve lever. A metallic gauge should be used, and very neat pocket instruments of the kind are sold in Paris. In frosty weather the rivet heads are liable to be snapped if the metal be not somewhat warmed by using hot water. The hydraulic ram kind of action on the sides is also much less likely to occur if a rather narrow force pipe be used for the pump.

There can be no doubt that it would be a valuable thing to be able to employ some means of measuring the permanent and temporary

* "Instructions to be Observed in the Management of Steam Boilers in the Royal Gun Factories."

extension of volume, if any, produced by the hydraulic test. It is probable that a boiler, as it gets old, and takes a permanent set under the pressure, also increases in volume; so that it doubtless holds a few gallons more than it did when new. An ingenious plan for measuring the increase of volume is recommended in the Bavarian regulation. After the boiler is filled, the amount of water forced in is measured by pumping it from a vessel marked with divisions. When the pressure is removed, the boiler contracts more or less, forcing out at least a portion of the water; the amount remaining is supposed to give the dilatation of volume of the boiler. The difficulty in the use of this plan would probably consist in the presence of air in the water itself, and any which might chance to remain in the boiler. That in the water might be greatly diminished, or at any rate brought down to a constant amount by boiling; but there would be no precise security against any air in the boiler, and as the weight of the air absorbed by water (according to a well known law) is in proportion to the pressure, it would be taken up by the water, thus falsifying the indications when the pressure was removed. On the other hand, a high temperature of the water would form an impediment to this absorption. The experiment is certainly worth trying. It might be very valuable with tubular boilers inaccessible from the inside, as any permanent set or deflection ought to be indicated by little or no water being compressed out by the contraction of the boiler on the removal of the pressure. As long ago as 1844, M. Jobard, of Brussels, in order to obviate the supposed injurious effects of the hydraulic blow of the water on the plates, proposed to fill the boiler with water, first loading the safety valves, and to then dilate the water, and consequently the boiler, by means of heat applied to the outside.* More recently, Dr. Joule, of Manchester, has used the same plan himself, proposing it for general adoption.† In addition to the loaded safety valve, he used a metallic pressure gauge "to be constantly observed, and if the pressure arising from the expansion of the water goes on increasing continuously without sudden decrease or stoppage until the testing pressure is obtained, it may be infered that the boiler has sustained it without having suffered strain." Another plan, also founded upon the same principle of the irregularities of extension of metals when the limit of elasticity is exceeded, has lately been proposed.‡ This consists in bringing an ordinary steam engine indicator in communication with the pump plunger as if it were a steam engine piston rod. The ordinates of the pencil diagram would thus give the pressure in the boiler, while the respective abscissæ would give the quantity of water pumped in at each stroke. As long as the limit of elasticity was not exceeded there would be a horizontal line, while a curved line would appear as soon as the sides began to take a permanent deflection. There seems to be a sort of contradiction in depending for results like these upon such irregular appearances as

* "Technologists," 1844, page 135.

† "On a Method of Testing the Strength of Boilers." Journal of the Manchester Philosophical Society, 1862, page 97.

‡ Polytechnisches Centralblatt, page 1337, 13th October, 1864.

the extension beyond the elastic limit. But all these proposals are undoubtedly worth trial in practice. Dr. Joule's plan has the merit of affecting the plates by both heat and pressure, thus bringing them under every day conditions.

(To be continued.)

Temperatures and Pressures of High Pressure Steam. By R. A. PEACOCK, C.E., Jersey.

From the London Artizan, June, 1865.

An examination of the following table—which has never been published before, and, with the exception of Dr. Fairbairn's experiments, is quite new—will satisfy the reader that from 25 lbs. per square inch up to 411·6 lbs. per square inch, the temperature increases as the $4\frac{1}{2}$ root of the pressure. The greatest variation from M. Regnaults experiments is with his temperature of 300° Fahr.; such variation, however, is less than $\frac{1}{4}$ per cent., viz: ·232, or 1 in 431. It will be further observed that even with regard to that small variation, the result ought to be considered as modified by the very close approximation of the calculation to Dr. Fairbairn's experiments with a temperature only a little less, viz: 292·53° Fahr., for which the calculation gives a difference of only ·017 per cent., or 1 in 5882. With M. Regnault's temperature of 410° Fahr., the calculation is all but identical, the difference being only ·002 per cent., or 1 in 50,000, while with his last temperature, viz: 447° Fahr., the difference between experiment and calculation is still unimportant, being no more than ·159 per cent., or 1 in 629. And it may be further observed, that the formula, *Temperature increases as* $4\frac{1}{2}$ *root of pressure*, is, so to speak, still more moderate than M. Regnault's own formula; because it will be seen that the former requires 447·71° to give the pressure of 411·6 lbs., whereas M. Regnault's formula gets that pressure with 447° Fahr. only. That is to say, if both formulæ were to be applied (hypothetically) to calculate very high temperatures of, say, 2000° or 3000° Fahr., M. Regnault's formula would give greater pressures than the other. Probably the means do not exist for ascertaining how far either formula differs from fact at those high temperatures.

Yet, although exact knowledge does not exist, we are fortunately not without some indications of the force of steam pressure at very high temperatures. The Rev. John Michell wrote a very valuable paper, in which he contended that earthquakes were caused by steam,* which paper does not appear to have gained as much consideration as it probably deserves. He says that in casting two brass cannon "the heat of the metal of the first gun drove so much damp into the mould of the second, which was near it, that as soon as the metal was let into it, it blew up with the greatest violence, tearing up the ground some feet deep, breaking down the furnace, untiling the house, killing many spectators on the spot with the streams of melted metal, and

* Phil. Trans. R.S., 1760, vol. xi., p. 447, &c.

Pressures per Square Inch.	Regnault's Experiments.	Dr. Fairbairn's Experiments.	As 4½ Roots of Pressures.	Differences.	Differences per cent.
lbs.	Temp. F. deg.	Temp. F. deg.	Temp. F. deg.	deg.	deg.
24·998	240		240·244	— ·244	— ·102
26·5		242·90	243·375	— ·475	— ·195
27·3518	245		245·093	— ·093	— ·038
27·4		244·82	245·188	— ·368	— ·150
27·6		245·22	245·585	— ·365	— ·149
29·8753	250		249·946	+ ·054	+ ·022
32·5899	255		254·824	+ ·176	+ ·069
33·1		255·50	255·705	— ·205	— ·080
35·5005	260		259·715	+ ·285	+ ·110
37·8		263·14	263·362	— ·222	— ·084
38·6169	265		264·617	+ ·383	+ ·145
40·3		267·21	267·137	+ ·073	+ ·027
41·7		269·20	269·17	+ ·03	+ ·011
41·9587	270		269·543	+ ·457	+ ·170
45·5259	275		274·474	+ ·526	+ ·192
45·7		274.76	274·71	+ ·05	+ ·018
49·3332	280		279·417	+ ·583	+ ·209
49·4		279·42	279·50	— ·08	— ·029
51·7		282·58	282·34	+ ·24	+ ·085
53·3953	285		284·374	+ ·626	+ ·220
55·9		287·25	287·29	— ·04	— ·014
56·7		288·25	288·20	+ ·05	+ ·017
57·722	290		289·34	+ ·66	+ ·228
60·6		292·53	292·48	+ ·05	+ ·017 $=\frac{1}{5882}$
62·328	295		294·319	+ ·681	+ ·231
67·2231	300		299·306	+ ·694	+ ·232 $=\frac{1}{431}$
72·422	305		304·302	+ ·698	+ ·229
77·9345	310		309·303	+ ·697	+ ·225
83·7802	315		314·315	+ ·685	+ ·218
89·9689	320		319·332	+ ·668	+ ·209
96·5104	325		324·352	+ ·648	+ ·200
103·4292	330		329·381	+ ·619	+ ·188
110·7302	335		334·412	+ ·588	+ ·176
118·433	340		339·446	+ ·554	+ ·163
126·5523	345		344·486	+ ·514	+ ·149
135·1028	350		349·527	+ ·473	+ ·135
144·0992	355		354·565	+ ·435	+ ·123
153·5562	360		359·614	+ ·386	+ ·107
163·4934	365		364·660	+ ·340	+ ·093 $=\frac{1}{1075}$
173·9266	370		369·705	+ ·295	+ ·079
184·8574	375		374 750	+ ·250	+ ·067
196·3234	380		379·795	+ ·205	+ ·054
208·3284	385		384·838	+ ·162	+ ·042
220·8871	390		389·876	+ ·124	+ ·032
234·024	395		394·918	+ ·082	+ ·021
247 7538	400		399·949	+ ·051	+ ·013
262·0912	405		404·980	+ ·020	+ ·005
277·0509	410		410·007	— ·007	— ·002 $=\frac{1}{50000}$
292·6525	415		415·029	— ·029	— ·007
308·9156	420		420·047	— ·047	— ·011
325·85	425		425 058	— ·058	— ·014
343·4753	430		430·063	— ·063	— ·015
350·7224	432		432·063	— ·063	— ·015
411·6*	447†		447·71	— ·71	— ·159 $=\frac{1}{629}$

* = 28 atmospheres, and † = 230·56 centigrade. See Rev. R. V. Dixon's "Treatise on Heat," p. 183.

scalding others in the most miserable manner." These great effects were evidently produced by the steam of a few ounces of water only, for it is called merely "damp," and it must, therefore, have been very powerful steam. Now, according to the late Professor Daniell, F.R.S., brass melts at 1869° F., but the heat of the steam could not have been as much as that, because, amongst other reasons, a portion of the heat must have been taken up by raising the temperature of the "damp," and the "mould," and the neighboring sand. If the temperature of steam could have been 1869° F., the hypothetical pressure would have been by the formula, 114 tons per square inch; but the real force consequent on the reduced temperature most likely was considerably below 100 tons. What is intended to be inferred is, that the pressure of steam continues to increase at all events as high as up to water converted into steam by an initial heat of 1869° F. The law of increase may either be according to either of the formulæ, or to some of the other well known formulæ, or to some other unknown law, but at all events the force *had* continued to increase.

The columns headed "Pressures per square inch," so far as they relate to M. Regnault's experiments, are reduced from Table I, pp. 259–260, of the Rev. R. V. Dixon's "Treatise on Heat,"* where he gives the pressure or force in inches of mercury. He was elaborately accurate in reducing M. Regnault's temperatures and pressures to English denominations, having calculated the values of the constants from Vlacq's tables, in which the logarithms are given to ten places of decimals, (p. 252.)

Further particulars of this formula appeared in the *Artizan* of January and February, 1864.

The present writer exhibited before the Mathematical and Physical Section of the British Association at Bath (but did not read) a MS. containing about sixty evidences of the presence of water in some of its forms, in every species of natural disturbance of the earth's crust. Additional evidences have since been collected, and the whole number now amounts to about seventy; and a summary of these evidences gives the following results:

Humboldt, who, perhaps, personally inspected more volcanos than any other man who ever lived, and Sir Humphrey Davy, both condemn the alkaloid theory as co-operative only; and

1. We have Humboldt, Davy, Lyell, Von Buch, Dana, Sir William Hamilton, Dr. Scherzer, and three anonymous writers, testifying to the ejection of abundance of steam from volcanos generally, and some of them from Vesuvius in particular.
2. Steam is ejected from earthquake fissures.
3. It is *said* that steam is exclusively the moving force in geysers, and *proved* that it issues from them in great force and abundance.
4. Large rocks are ejected by steam.
5. Submarine volcanos necessarily produce steam, and one of them has been active for 2000 years. Earthquakes often accompany. Steam was very active when Graham Island rose from the Mediterranean.

* Hodges and Smith, Dublin, 1849.

6. In 1822, at Galangoon, in Java, the waters of the river Kunir, which flowed from the flanks of a volcano, became for a time hot and turbid. About two months after there was a loud explosion, and immense columns of hot water, boiling mud, burning brimstone, ashes, and lapilli were projected like a water-spout, with prodigious violence, and to a great distance. The first eruption lasted nearly five hours, and on the following days the rain fell in torrents, and the rivers, densely charged with mud, deluged the country far and wide. At the end of four days, a second eruption occurred more violent than the first, in which hot water and mud were again vomited, and great blocks of basalt were thrown to a distance of seven miles. There was at the same time a violent earthquake, and 2000 people were killed.

7. Hot or boiling water and rocks are ejected from volcanos, and sometimes accompanied by earthquakes. A large lake has its level lowered during a volcano and earthquake, and two small rivers disappear and break out again as hot springs.

8. Water, often hot, is ejected from earthquake fissures, and from risings and sinkings of strata.

9. Earthquakes are fed by water.

10. Deposits of water, ice, or snow are ready to descend into volcanos by gravitation.

11. Active volcanos are fed by water, and absorb all the rain which falls upon them.

12. Volcanos in action, earthquakes, hot water, and increased heat of hot springs, are sometimes all connected together.

13. The lava of five volcanos emits copious volumes of steam or gas.

14. In extensive reading on the subject, the writer has found no reason to believe, nor any allegation, that steam or its components is ever absent.

15. "A deplorable accident has lately happened at Etna by an explosion caused by the contact of burning lava with some cistern or watercourse, by the effects of which a number of sappers are reported to have lost their lives, but the particulars are not known."* Thus steam and hot water have literally a great deal to do with volcanos and earthquakes, for steam cannot be idle.

The ancient Greeks used to personify everything. Would they not, if they had known all these things, have been likely to represent Etna pointing to the explosion of the cistern as the principle of her own explosions? And ought not the same point to be a grave question now?

Sir Henry de la Beche and Mr. L. L. Dillwyn made experiments† by which they found that Cornish granites and elvans melted with a heat about equal to that required for melting malleable iron, which is the greatest heat that can be obtained in a smith's forge. But even

* Mr. J. J. Jeans, British Vice-Consul at Catania, Feb. 4, 1865. See *Illustrated London News*, Feb. 25, 1865.

† Sir H. de la Beche's "Cornwall," p. 191, foot note.

with this great heat black non-lithia micas remained unfused. We may, therefore, safely assume, for these and other reasons, that the heat of melted lava is not less than 3000° F. But since we have seen that the force of steam has increased according to some unknown ratio up to an initial temperature of 1869°, it would be contrary to all precedent, and therefore rash to assume that there is not also a further increase with 3000°.

Supposing, for the sake of argument, and by the way of illustration, (for the moment only,) that the temperature continues to increase as the $4\frac{1}{2}$ root of the pressure until the net thermometrical temperature of the steam has become 2200° F., which Professor Daniell found is the heat of melted gold. Then the (hypothetical) pressure would be 237,494 tons per square inch, which, by calculation, would suffice to propel a certain large mass of granite from a supposed focus three miles below sea-level up to one mile above sea-level—in all four miles of vertical height, inclusive of the resistance of the air, which is very great. It would follow, then, that it is *possible* that there *may be* such a thing as steam powerful enough to produce the greatest effects of earthquakes and volcanos, for 2200° is by no means the maximum temperature attainable.

For the Journal of the Franklin Institute.

Cut-offs.

The controversy between the Navy Department and the builders of the *Algonquin*, enlivened by the trenchant letters of the constructor of her engines, has forced on public attention the subject of expansion by cut-offs. The sympathies of many practical men are with the builders. They endorse their confidence in the superior qualities of the engines, and their defiance of official opponents. Still, the principles of physics, on which the result depends, are inexorable and insensible to moral suasion or censure. There are those who think the mighty agent, upon which progress depends more than on anything else, has passed through every form and phase of trial, and that its value as a motor is exhausted in modern engines; others, with more reason, believe that, so far from our knowledge of it being complete, much of importance is yet to be acquired. Unacquainted with the parties contending and their experiments, without a shadow of interest in cut-offs, or the slightest prejudice in favor of or against them, I think it has happened to them as to other devices, to which credence has been given without due examination, and opinions taken up on trust. At the risk of having the remark applied to myself, I think they are imperfectly understood. The following thoughts are thrown out with the sole view of aiding in the discovery of the truth.

To economize steam by expansion has been a desideratum for well nigh a century, and nothing conclusive has been attained. Conflicting opinions are still rife, and the government has charged a commission of experts to solve the problem by a fresh set of experiments. I have

no faith in doubtful or hazy explanations of mechanical matters, nor is there any reason why any one should. Whatever is uncertain vanishes when thoroughly looked into, and every man of ordinary talent and persistance can do that. Such is the case with steam.

Although the leading element in the civilization of our orb, and one in all probability never to be superseded, the properties of aqueous vapor are as palpable and plastic as those of other bodies. As complete control of it may be had as of them. It is weighed in the same scales and its quantities ascertained by the same vessels of capacity as liquids and solids. A pound of it is a pound of water vaporized. The mode of using the measures is somewhat different than with liquids, but not less rigid and correct. One holding a cubic foot of water has to be emptied and filled afresh until the required number is made up, whereas with steam several feet are commonly contained in the space of one, the number being indicated by the pressure. Hence *pressure* and *quantity* are *complements and explicatives of each other.* As volume increases, pressure diminishes, and *vice versa*, the quantity remaining the same. The smaller volume may contain the larger: Five cubic feet whose pressure is 40 lbs. on the inch, contains ten feet of 20 lbs., or 20 feet of 10 lbs., all three being equivalents in cost, quantity, and power. The knowledge of this is essential to a correct appreciation of cut-offs, since as much, or even more, steam may be let into a part of a cylinder than would suffice for the whole.

It will be understood that I speak here of *natural steam*, not of that doctored by heat and more or less decomposed after actually or virtually leaving the boiler,—steam, of which every cubic foot contains, in round numbers, a cubic inch of water, and in the using of which nothing is left in doubt—nothing to mystify or perplex,—steam, whose power is increased by increasing its quantity, just as more heat is obtained by consuming more fuel, more light by turning on more gas, more wind power by enlarging sails to catch more of it, as the force of a gun is increased by adding powder to the charge, and that of men and animals by increasing their numbers. To double the power of steam, the fluid must be doubled. Such we take to be the only reliable theory of forces, whether the motive agent be an elastic fluid, a liquid, a solid, or a living body. Yet vast amounts of time, talent, and money, have been and are still being spent to prove steam an exception. Superheating it may, in certain cases, be found useful to prevent premature condensation, but that its value as a prime mover is thereby increased has yet to be established. It adds nothing to the substance of the fluid. Another query is, whether any alleged gain does not cost, all things considered, as much or more than it is worth.

If a sluice-gate be arranged to deliver more water on one part than on another of an overshot wheel, no more power could be got from it than from the uniform discharge of the same quantity upon it. The power would be in the weight of the liquid, and that would be the same in both cases. So with steam: it is the quantity let into the cylinder that determines the power, not the mode of letting it in. This is, however, questioned. Advocates of cut-offs insist that when the whole force

or charge is opened on the piston in the first part of the stroke and left to expand and follow it to the end, a better effect is obtained than from an equal (or even greater) charge let in regularly from the beginning to the end, or near the end of the stroke.

It has been thus accounted for: "By the momentum given to the matter which the engine is moving—it may be the fly-wheel, or the steamboat itself, or the train of cars, all of which, when once set in motion, will not suddenly stop, even though all power were suddenly suspended from driving them, and which therefore will continue to go on under the diminished pressure of the expanded steam. Thus you see that when the steam is cut off from the cylinder, that which is in it continues to push on the piston with diminished force, but still with some force; and as the piston cannot stop, it absorbs, and through the wheels which it drives gives out again to useful effect whatever pressure is thus spent upon it, just as your watch will run all day, although the spring which drives it grows weaker and weaker as it is relaxed.

"The gain which can be obtained from the use of expansion is measured by the extent to which you carry it; or, in other words, how short you cut off the steam in the cylinder.

"Ten expansions will do three times and a third as much work as no expansion, using the same amount of fire and steam."

Progressive movements dependent on varying momenta abound in every department of nature. Animals that go forward by springs or leaps are examples. The path of some birds through the air in a succession of ascents and descents—a series of undulations or curves—rising by the action of their wings and descending without it. The principle of thus applying force is therefore a sound one, and the question is its adaptation to artificial machinery and propulsion. We find it confined by the Great Engineer to organisms specially fitted for alternations of leaps and stops, and whose functions are incompatible with uniform speed. Neither the locomotive organs of natural machines, nor the conditions under which they act, are applicable to ours, nor ours to them. There is not a rotary propeller in nature, while we have in the *wheel* the most equable and perfect instrument of progression. Its supreme excellence is its complete adaptation for receiving and transmitting continuous motion without jarring the masses it moves, and consequently without a varying momentum. With cut-offs there is of necessity an inequality of pressure on the pistons, and therefore an inequality of motion in bodies impelled by them,—an effect fatal to stability and durability.

If the second proposition in the quotation is to be received, the laws of force and resistance would seem to be at fault.

The next dictum is specific and not to be misunderstood. Could it be proved, a chief niche in the world's Walhalla would be due to its author. That by the same quantity of steam more than three times the work can be performed with a cut-off than without one is incredible, and if true a miracle almost as great as making three gallons of water out of one. If the resistance were greatest at the beginning of the stroke, and fell down to zero at the end of it, there might be

cause for some gain, but, so far from that, it may be considered uniform in bodies moved by steam, whether ploughs, ships, cars, or manufacturing mechanisms. Whatever may be said to the contrary, we must continue to believe, till controverted by facts, that there can be no saving of steam power by substituting a succession of impulses for continuous pressure, except in cases where the resistance rises and falls with the piston's movements. Whether there are such cases we know not, but it is certain that sudden changes of force and velocity are not the things for steam machinery, no more than are springs and leaps (sensible or insensible) for bodies moved by it.

The popular idea is illusive. It is the impression of many that when the cut-off acts at half-stroke, half is saved; at one-third, two-thirds; and at one-fourth, three-fourths. They forget that pressure indicates quantity. Engines with cut-offs of necessity use steam of greater tension than others, and the less the charge the greater the tension. The only difference is that one class uses small volumes of high pressure, and the other large volumes of lower pressure, the requisite quantity being the same in both. An engine is worked with steam of 100 lbs. on the inch, and cuts off at half-stroke. The mean pressure of the latter half is, therefore, 75 lbs, and that of the whole stroke 87 lbs. on the inch. Observe that twice the force is expended on the first half than suffices for the latter half, and (the resistance being the same) twice the amount required. Where then is the difference in the amount consumed between charging the cylinder with 87 lbs. steam, and with it varying from 100 to 50 lbs. In every case as much of the fluid *must* be admitted as will push the piston to the end of the stroke, whether sooner or later cut off. Another engine has a cylinder of the capacity of twelve cubic feet; and requires steam of not less than 12 lbs. per inch pressure. This does the work without a cut-off. Suppose it be determined to apply one and cut off at half-stroke, would not the tension have to be raised to 24 lbs. on the inch, if cut off at one-third to 36 lbs., and if at one-fourth to 48 lbs? In fine, does it not follow that *theoretically* there is no more to be gained by cutting off at a quarter than at half-stroke, and no more by that (unless in special cases alluded to) than with no cut-off at all. To determine how far practice conforms to theory there is a conclusive experiment—apply the same *quantity* of steam used with a cut-off to the same cylinder without one.

E.

On the Erith Explosion, and the Repair of the Thames Embankment.

By Lewis Moore.

Read before the Society of Engineers, Nov. 7th, 1864.

From the London Mechanics' Magazine, November, 1864.

On the south side of the river Thames, between Woolwich and Erith, are several magazines used for the storage of gunpowder, belonging, some to Government, and some to private firms engaged in the manufacture of gunpowder. These are situated within a few yards of the

bank of the river, for the convenience of loading and unloading by water, that being the most convenient and economical, as well as the safest method of transit. These magazines occur at intervals of half a mile or thereabouts. In the river, moored close to the north shore, were, until recently, three or four large hulks, used also for the government storage of powder. Now, however, there exists but one, that being moored between North Woolwich and Barking Creek; the others, which formed part of the Government store at Purfleet, have been removed. On the north bank of the river there appears to be only one magazine in this neighborhood beside the royal magazine at Purfleet. Full details of the arrangements of these magazines have so recently appeared in the public journals that it is unnecessary here further to notice them, save as to their relative positions with regard to the subject of this paper; and this will be clearly seen on reference to the map of the general locality (No. 1).

The scene of the recent explosion was on the south side of the river, in the Erith and Plumstead Marshes, and the magazines which were destroyed were the property of Messrs. John Hall and Sons, of the Faversham Mills, and of the Elterwater and Lowood Gunpowder Companies. The relative positions of these magazines to each other, and to the bank of the river and the adjoining cottages, &c., will be clearly seen on reference to diagram No. 2, which is from actual survey. The magazine of Messrs. Hall and Co. was a substantial brick building, 50 feet square and two stories high, and was situated at the back of the river wall or embankment, on the marsh, at a level of 7 feet or 8 feet below Trinity high-water mark. From this magazine a jetty projected into the river to low-water level. This jetty was used for the shipment of gunpowder, and crossed the river wall on the level of the footpath. In this magazine, and in two barges, which at the time of the explosion were moored, one at the end and one at the side of the jetty, there were about forty-two tons of gunpowder. The magazine of the Elterwater Company was situated 64 yards to the eastward of Messrs. Hall's stores. This building was a similar construction, and measured 50 feet by 28 feet, and contained about $4\frac{1}{2}$ tons of powder. The next nearest magazines were those of Messrs. Curtis and Harvey, which are about 700 yards distant to the westward. The buildings adjacent were the manager's house and two or three cottages, inhabited by men employed at the magazine.

The river wall at this point consisted of an ordinary puddled clay embankment (the top of which was about 4 feet 6 inches above Trinity high water), battered about two to one, and faced on the river side with stones, to protect it from the wash of the sea; along the top was a foot-way about 4 feet or 5 feet wide. At the foot of the wall, on the land side, was the marsh that it reclaimed, and on the river side a shelving mud bank, falling at about the rate of one in six or seven to low water. The section will be clearly seen in diagram No. 3.

Trinity high water is 12 feet 6 inches above ordnance datum, but the spring tides have been known to rise to a level of 16 feet—14 feet being the height to which they frequently rise. At the time of the

explosion which took place at twenty minutes before seven o'clock on the morning of Saturday, the first of October last, the tide was ebbing, and was within an hour and a half of low-water—a most fortunate circumstance; for, had the accident occurred one hour later, it would have been impossible to reinstate the wall, and the marshes, as well as some of the surrounding country, must inevitably have been inundated, as it was impracticable (as afterwards proved) to have contended with the flowing tide in the limited time available. Of the immediate cause of the accident it will be here unnecessary to speak, as that will probably never be known; but with regard to the results there is more tangible matter to deal with. From the evidence afforded by the displacement of earth at various points, there is every reason to believe that there were three distinct explosions, occurring probably in the following order: 1. The barge lying alongside the jetty and near the bank; 2. Messrs. Hall's magazine; and 3. The Lowood Company's magazines. The barge at the end of the jetty is presumed to have been empty, as no disturbance appears in the soil beneath where she lay, whereas in the other cases the earth was blown out to a considerable depth, presenting the appearance of a smouldering crater, with fissures in all directions. The reasons which lead to the supposition that the explosions occurred in the order above stated are that portions of the river wall were found in the hole or pit caused by the barge exploding, and this could only have been the case by the magazine exploding after the barge, and forcing the wall back towards the river, thrusting portions of it into the pit already formed by the barge. Had the magazine exploded first and thus ignited the barge, the ground beneath her would have been clear of fragments, as the wall would probably have been blown inland by the last explosion. The magazine last referred to would communicate with that of the Lowood Company, which, in its turn, was demolished. The concussion caused was felt from 60 to 100 miles off; this was the result of the explosion of $46\frac{1}{2}$ tons of gunpowder or 1040 barrels, each containing 100 lbs. The effects to property, both immediate and remote, are universally known; as regards the river wall, a breach was made of 130 feet in length, the earth being cleared away 8 feet or 10 feet below the level of the marsh, exposing the whole of the country to the rising tide for about five hours every high water, or twice in twenty-five hours. The extent of land positively imperilled would be about 4000 acres; and should it have passed Woolwich and Greenwich by the large sewer it might have done immense damage, the whole of the southern and eastern side of London being more or less below the level of high water. The full estimate of the impending calamity can only be realized by those acquainted with the levels of the localities referred to, and the character of the banks of the Thames. Diagram No. 4 shows a section of the river wall after the explosion, the dotted line shows a contour of the temporary dam. In an able article in the *Builder*, upon the subject of the catastrophe, the fortuitous conjunction of circumstances is thus described: "Every circumstance of time and tide, availability of competent direction, presence of men at the works of the main drainage,

vicinity of a great and disciplined military force with tools and appliances, and even the soil at the spot, happened to be favorable; and a more serious disaster than has occurred within recollection, by a breach in an embankment of the Thames, was, by the greatest exertions, stayed off and at length averted. The instance may be instructively compared with the experience of previous accidents, as related in various books, where the loss to landowners, and the injury to the navigation of the Thames, through the year's duration of breaches, and by the repeated failures of attempts to close them, is graphically related."

The author of the paper, residing in the locality, was enabled to be on the spot within half an hour of the explosion, and seeing that the sufferers were properly cared for, he proceeded to the immediate repair of the wall, although, at the time, the reinstatement of the wall before the return of the tide appeared hopeless, such was the magnitude of the gap. The first step was to set to work the men who were fortunately present, in number about forty—these were set to puddle the rents and deep fissures in the hole caused by the exploded barge, and which were below low-water level, but were temporarily protected by the fragments upheaved around the edge of the hole; had not this been done before the water came into the hole, it could never have been got at again, and the whole superstructure, however solid, must have been undermined and washed away. It may be readily inferred that the bases of operations were of the worst possible description, being lumps of earth and clay separated by large fissures several feet in length, and extending under the intended dam. The next thing was to send for assistance from the nearest point; fortunately this was obtainable at the Crossness works, about a mile off, and at the garrison at Woolwich, about four miles distant from the spot. At about ten minutes before nine o'clock, the call was promptly responded to by the arrival from the Crossness works of about 350 navvies, with their picks, barrows, &c., who came none too soon to complete the puddling of this treacherous foundation before it was covered by the tide. Between ten and eleven o'clock 1500 military arrived, fully equipped with some appropriate implements, and they devoted themselves entirely to the backing up with immense quantities of earth, the work which the navvies were puddling in front, thus making it sufficiently substantial—consistent with speed and means at hand to contend with the now rapidly rising tide. In this, as is well known, by a manful struggle, they only just succeeded—racing, as it were, inch by inch with the rising waters.

Having given a general outline of the subject of the paper, it is now necessary to consider in detail the means employed and the measures taken to prevent the ingress of the water.

The first and greatest difficulty that presented itself was the portion blown out by the barge in front of the river bank, and below low water, inasmuch as the soil was very much broken up and disintegrated over a large area, and the time during which puddling could be done was exceedingly limited.

It may be here mentioned that an erroneous impression prevailed among some persons present that it would be necessary to dig out this portion to a good bottom, in the usual manner of commencing the construction of a river wall, and the author had much difficulty in persuading them that immediate puddling of the fissures and broken ground below low-water mark was the only hope of succeeding, inasmuch as the cutting a grip would have occupied all the precious time employed in filling up. This puddling was most important in order to prevent percolation, the danger most necessary to be averted. When the navvies arrived from Crossness, they were immediately set to continue this important part of the work, and also the filling of the actual gap. It required some little time to arrange the number of men to advantage, but, being accompanied by able superintendents, they were soon allotted to their separate works of digging clay—wheeling it to the spot, and carrying water for the punning, where the clay was well worked with iron punners.

While the puddling, &c., was being vigorously carried on by this large force of men, the military arrived, commanded by General Warde and Colonel Hawkins, R.E. The difficulty of immediately rendering available, without confusion, the labor of all these men in so small a compass and on the spur of the moment may readily be imagined. With the greatest promptness, Colonel Hawkins adopted the suggestions offered him by the author, as to the method of proceeding. Several barrow roads were laid leading to the gap, numbers were employed in digging and loosening earth, filling and wheeling. The number of implements available for the use of the soldiers was, of course, limited; but, nothing daunted, they were formed into lines between the barrow roads, and passed from hand to hand towards the gap the lumps of earth and clay dug up by those at the back, the whole of the clay and earth for that purpose having to be brought from a distance of 60 or 70 yards by the barrow roads, and by hand, the soldiers passing lumps from one to another for this distance, which, when deposited in place, were immediately punned down perfectly solid. Having to deal with some 20 feet head of water, it was necessary to extend the width of the dam at the base, which absorbed an incredible amount of earth, the width of the breach being 130 feet. When the tide had reached and filled the front hole, it was found that the level of the water was within 2 feet or 3 feet of the top of the progressing work. The tide rising very rapidly, fears were entertained that sufficient soil could not be obtained to enable the work to keep ahead of the tide. At this juncture, the military produced a quantity of bags used for making sand-bag batteries, and a number of men were set to fill them with the soil at the back of the work. These bags were at first being thrown in indiscriminately, when the author directed that they should be laid at the back of the puddled face in the form of an arch on plan, to receive the horizontal pressure of the water. These bags were laid in courses, as shown in diagram No. 5, and punned so as to come in perfect contact. By this means the bank could be raised of sufficient strength with about one-half the material, and the disposition of the

men was so arranged as not to interfere with the other parts of the work. In this way about 3000 bags were used, and it was satisfactory to find they answered the purpose admirably; but even with this assistance, the tide was following the work very closely.

An alarm was now raised that the water was coming in, and it became apparent that there was considerable percolation under the dam —probably through the broken ground upon which so much labor had been bestowed in puddling—and making its appearance many yards at the back of the work, it was difficult to arrive at the treacherous point. This was most disheartening by the knowledge that a small stream would soon increase in newly made earthwork and undermine the whole. The exertions were redoubled, but it is feared that these would have proved of no avail, but for the timely settlement of the structure and consequent compression of the substrata. By this providential circumstance the leak was staunched, so that the settlement, apparently a source of great apprehension, proved really a matter for congratulation. Sole attention was now turned to raising the bank and protecting the face from the wash caused by passing steamers. Timber breakwaters were hastily constructed and floated in front of the work, and this in a great measure protected it from being undermined. By half-past one the tide was at its highest, and the bank was but a few inches above it; the structure successfully withstood the pressure of the water, but it was evident to all that the backing up must be continued before the danger was past, and the men, therefore, worked on until the tide had far receded. A large staff of men continued the operations throughout the night of Saturday.

On Sunday morning the bank was found to have settled some four feet, and, in consequence of high wind from the east and a heavy sea running, threatening to undermine the works, the author telegraphed to General Warde, Commandant at Woolwich, for 500 sappers and miners, who arrived in time to reinstate the dam. The whole of the past month has been occupied in restoring the wall to its original condition, and it is now as secure as any other portion of the embankment.

Breaches of the river wall reclaiming the marshes from the river Thames have been very frequent in times gone by. These have not arisen from causes similar to the one under consideration, but from high tides, defective sluices, and even rat-holes. In 1527 the river made an irruption at Plumstead and Erith, and so much land was submerged that it was not all regained until 1590, a matter of sixty-three years. This breach occurred within half a mile of the present one, and there are now existing traces of the inland embankments by which it was reclaimed piecemeal. In the time of Henry the Eighth, the marshes of Plumstead and Lesnes, now the Woolwich practicing ground, were submerged by the water coming in from the Erith breach. But the most recent, as well as the most important, was the Dagenham breach, which occurred in 1707, at a point exactly opposite the southern or fall works of the London sewerage. Continued attempts to stop this breach were made for eight years, but without suc-

cess, when Captain Perry undertook to reclaim it. At this time the breach is stated to have been on one occasion 50 feet below low water, or seventy feet below high water, caused by the ingress and egress of the flood and ebb tides. Captain Perry, it is stated, employed three hundred men for five years before he succeeded in stopping this breach, making thirteen years in all, during which time an immense quantity of the marshes were washed into the river, greatly obstructing the navigation of that important highway. The means he adopted were, first, forming sluices in the river wall to reduce the scour by allowing freer access to the water, and after so doing he drove dove-tailed or grooved piles from either side of the breach, protecting them as he went on with clay. The increased scour caused by this impediment threatened to deepen the channel so as to be beyond the reach of piles, and if the depth above stated was correct, it would have been impossible to have succeeded by this method; so the inference is that he chose a shallower portion of the breach; certain it is that he did succeed, although at a ruinous cost.

The Dagenham breach began with the failure of a sluice which had been allowed to get out of repair, and quickly extended from a gap of fourteen feet, and ultimately led to the obliteration of a thousand acres of land. But that was not all; about one hundred and twenty acres were actually washed away into the bed of the river by the flow of sullage, and the soil so washed formed a bank about a mile in length, reaching half-way across the river.

Perry in his work on Dagenham breach proceeds to explain how this sullage, driven into the river, was deposited at the mouth of the breach, and above as well as below it, in the reaches of the Thames. He remarks that the deposit had been particularly detrimental to Erith Reach; and that even in Woolwich Reach, as he had been informed, the depth of water was lessened. All breaches, he observes, must be attended with a considerable flow of sullage into the river. After mentioning breaches that had occurred before his time, including one in the levels of Dagenham Beam, not three years and a half since, and several near Dagenham since he had been concerned there, he says, he attributes all such breaches, not to any damage from the tides washing down or running over the tops of the banks or wells, but to the bad workmanship, decay, or defect of the sluices or trunks which are made for the drain of the levels, &c., and he alludes to sluices made of wood as a prevailing custom in England, and as generally insecure and unskilfully placed. He recommends, therefore, a law to oblige all sluices on the banks of the Thames to be made with stone, cemented with tarras. The reasons why they have not been made so, he thinks, are, first, that men in England are not very willing to depart from the way of their fathers; and, secondly, the matter of foundations. He argues, however, that if the foundations were constructed after the manner of buildings in Holland, the sluices might be formed of stone, or a sort of brick, as in Holland and Flanders, and might endure thousands of years.

The greater portion of the land bordering on the Thames, including

the south of London, indeed from Richmond to the Nore, is below the level of high water, and reclaimed by walls varying but little in their construction, the general character of which is an embankment, the face of which is puddled with clay to a slope of $2\frac{1}{2}$ to 1, and protected from the wash of the sea by a stone face. In some cases where the steepness of the bank necessitates a greater slope, the face is stepped, and at each step a row of stakes driven to keep the stone facing in place. In constructing these walls, a grip about 6 feet deep and 6 feet wide is cut into the marsh to be reclaimed on the site of the wall, and puddled before the bank is made to prevent percolation. These walls and the necesssary sluices for drainage require careful watching, for any portion failing would cause a catastrophe equal to the Dagenham or middle level inundation. The extent of these walls or embankments is very considerable, being about 300 miles in length.

It is a very remarkable circumstance that the marshes on the river side of the walls, still unreclaimed and termed "salt marshes," are invariably at a level of high water, whereas the land reclaimed is generally 5 feet or 6 feet below that level. Whether the constant action of the tide raises the land subjected to it, or whether the absence of that influence allows the level of the marshes to subside, or whether it is due to both these circumstances, is a fit subject for discussion, but, be it as it may, there is no question of the fact that they do so exist.

Another material point for discussion is furnished by the supposition that failure had attended the attempt to stop the recent breach, and that the waters had regained possession of their old territory, some seven feet deep at high water over an area of from 3000 to 4000 acres. Assuming this to be the case, the breach would be rapidly widened and deepened, and, were the old system adopted, the reclamation would occupy many years. It would be a work of from three to four times the magnitude of the Dagenham reclamation; and on the authority of Lambard, the land inundated by the breach which occurred in 1527 near the recent breach, as before noticed, was not all reclaimed in sixty-three years.

For the Journal of the Franklin Institute.

Limes, Cements, Mortars, and Concretes. Collected from the observations and experiments of Generals Gilmore and Totten, U. S. A., and MM. Vicat, Chatoney, Rivot, and Dupont. By CHAS. H. HASWELL, Civil and Marine Engineer, N. Y.

(Continued from vol. xlix, p. 367.)

No. 2.

Calcareous Mortar.—Being composed of one or more of the varieties of lime or cement, natural or artificial, mixed with sand, will vary in its properties with the quality of the lime or cement used, the nature and quality of sand, and the method of manipulation.

Mortar.—Lime, 1; clean sharp sand, 2·5. An excess of water in slaking the lime, swells the mortar, which remains light and porous, or

shrinks in drying; an excess of sand destroys the cohesive properties of the mass.

It is indispensable that the sand should be sharp and clean.

Turkish Plaster, or Hydraulic Cement.—100 lbs. fresh lime reduced to powder, 10 quarts linseed oil, 1 to 2 ounces cotton. Manipulate the lime, gradually mixing the oil and cotton, in a wooden vessel, until the mixture becomes of the consistency of bread-dough.

Dry, and when required for use, mix with linseed oil, to the consistency of a paste, and then lay on in coats.

Exterior Plaster or Stucco.—1 volume of cement powder to 2 volumes of dry sand.

In India, to the water for mixing the plaster is added 1 lb. of sugar, or molasses, to 8 Imperial gallons of water, for the first coat, and for the second or finishing, 1 lb. sugar to 2 gallons water.

Powdered slaked lime and Smith's forge scales, mixed with blood in suitable proportions, make a moderate hydraulic mortar, which adheres well to masonry previously coated with boiled oil.

The plaster should be applied in two coats laid on in one operation, the first coat being thinner than the second. The second coat is applied upon the first, whilst the latter is yet soft.

The two coats should form one of about $1\frac{1}{2}$ inches in thickness, and, when finished, it should be kept moist for several days.

This process may be modified by substituting for the first coat a wash of thick cream of pure cement applied with a stiff brush just before the plaster is laid on.

When the cement is of too dark a color for the desired shade, it may be mixed with white sand in whole or in part, or lime paste may be added until its volume equals that of the cement paste.

Khorassar, or Turkish Mortar, used for the construction of buildings requiring great solidity, $\frac{1}{3}$ powdered brick and tiles, $\frac{2}{3}$ fine sifted lime. Mix with water to the required consistency, and lay on layers of 5 and 6 inches in thickness between the courses of brick or stones.

Interior Plastering.—The mortars used for inside plastering are termed Coarse, Fine, Gauge or hard finish, and Stucco.

Coarse Stuff.—Common lime mortar, as made for brick masonry, with a small quantity of hair; or by volumes, lime paste (30 lbs. lime) 1 part, sand 2 to $2\frac{1}{4}$ parts, hair $\frac{1}{6}$ part.

When full time for hardening cannot be allowed, substitute from 15 to 20 per cent. of the lime by an equal proportion of hydraulic cement.

For the second or "brown coat," the proportion of hair may be slightly diminished.

Fine Stuff, (lime putty.)—Lump lime slaked to a paste with a moderate quantity of water, and afterwards diluted to the consistency of cream, and then allowed to harden by evaporation to the required consistency for working.

In this state, it is used for a "slipped coat," and when mixed with sand or plaster of Paris, it is used for the "finishing coat."

Gauge Stuff, or hard finish, is composed of from 3 to 4 volumes

fine stuff and 1 volume plaster of Paris, in proportions regulated by the degree of rapidity required in hardening; for cornices, &c., the proportions are equal volumes of each, fine stuff and plaster.

Stucco is composed of from 3 to 4 volumes of white sand to 1 volume of fine stuff, or lime putty.

Scratch Coat.—The first of three coats when laid upon laths, and is from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch in thickness.

One-coat Work.—Plastering in one coat without finish, either on masonry or laths, that is, *rendered* or *laid.*

Two-coat Work.—Plastering in two coats is done either in a *laying coat and set*, or in a *screed coat and set.*

The *screed coat* is also termed a *floated coat. Laying* the first coat in two-coat work is resorted to in common work instead of *screeding*, when the finished surface is not required to be exact to a straight-edge. It is laid in a coat of about $\frac{1}{2}$ an inch in thickness.

Except for very common work, the laying coat should be *hand-floated.*

The firmness and tenacity of plastering is very considerably increased by hand-floating.

Screeds are strips of mortar 6 to 8 inches in width, and of the required thickness of the first coat, applied to the angles of a room, or edge of a wall and parallelly, at intervals of 3 to 5 feet all over the surface to be covered. When these have become sufficiently hard to withstand the pressure of a straight-edge, the interspaces between the screeds should be "filled out" flush with them so as to produce a continuous and straight, even surface.

Slipped Coat, is the smoothing off of a brown coat with a small quantity of lime putty, mixed with 3 per cent of white sand, so as to make a comparatively even surface.

This finish answers when the surface is to be finished in distemper, or paper hangings.

Hard Finish.—Fine stuff applied with a trowel to the depth of about $\frac{1}{8}$th of an inch.

ESTIMATE *of Labor and Materials for* 100 *square yards of Lath and Plaster.*

MATERIALS.	Three Coats Hard-finished Work.		Two Coats Slipped Work.	
Lime, ...	4 casks,	$4·00	$3\frac{1}{3}$ casks,	$3·33
Lump lime for fine stuff, .	$\frac{2}{3}$ "	·85		
Plaster of Paris, ...	$\frac{1}{2}$ "	·70		
Laths, ...	2000 .	4·00	2000	4·00
Hair, ...	4 bushels,	·80	3 bushels,	·60
Common sand, ...	7 loads,	2·00	6 loads,	1·80
White "	$2\frac{1}{2}$ bushels,	·25		
Nails, ...	13 pounds,	·90	13 pounds,	·90
Mason's labor, ...	4 days,	7·00	$3\frac{1}{2}$ days,	6·12
Laborer, ...	3 "	3·00	2 "	2·00
Cartage, ...		2·00		1·20
Cost of 100 yards, . .		$25·50		$19·95

Concrete or Beton, is a mixture of mortar, (generally hydraulic,) with coarse materials, as gravel, pebbles, stones, shells, broken bricks, &c. Two or more of these materials, or all of them, may be used together. As lime or cement paste is the cementing substance in mortar, so is mortar the cementing substance in concrete or beton. The original distinction between cement and beton was, that the latter possessed hydraulic energy, whilst the former did not.

Hydraulic.—$1\frac{1}{2}$ parts hydraulic lime measured when unslacked, $1\frac{1}{2}$ parts sand, 1 part gravel, 2 parts of a hard limestone broken.

This mass contracts $\frac{1}{5}$th in volume. Fat lime may be mixed with concrete, without serious prejudice to its hydraulic energy.

Various Compositions of Concrete.—Forts Richmond and Tompkins, U. S.

Hydraulic.—308 lbs. cement = 3·65 to 3·7 cubic feet of stiff paste. 12 cubic feet of loose sand =9·75 cubic feet of dense.

For Superstructure.—11·75 cubic feet of mortar as above, and 16 cubic feet of stone fragments.

In the foundations of Fort Tompkins, about one-twelfth of its volume was composed of stones from $\frac{1}{4}$ to $\frac{3}{4}$ of a cubic foot in volume, rammed into the wall as the concrete was laid.

Sea Wall.—Boston Harbor.

Hydraulic.—308 lbs. cement, 8 cubic feet of sand, and 30 cubic feet of gravel. The whole producing 32·3 cubic feet.

Superstructure.—308 lbs. cement, 80 lbs. lime, and 14·6 cubic feet dense sands. The whole producing 12·825 cubic feet.

TOTAL *Cost of Labor and Materials Expended in laying Concrete Foundation at Fort Tompkins, during the year* 1849.

Labor.

Wages of sub-overseer, 42·2 days at $2 per day,		$ 84·40
" mason, setting planks 82·8 days at $2 per day,		165·60
" laborers (assisting), 153·6 days at $1 per day,		153·60
" laborers transporting and ramming concrete, 2,971·8 days at $1 per day,		2,971·80
Total cost of labor,		$3,375·40

Materials.

4,096 casks cement at 85 cents,	$3,481·60	
12,288 " sand at 3 cents,	386·64	
20,480 " broken stone at 8 cents,	1,638·40	
		$5,488·64
Total cost of labor and materials,		$8,864·04
Total number of cubic yards of concrete laid, excluding the stone masses rammed in,		$3,606\frac{11}{27}$
Cost per cubic yard of pure concrete,		2·46
Deduct for stone masses rammed in,		·20
Cost per cubic yard as laid,		2·26

COST *of Masonry, of various kinds, per cubic yard, and the volume of Mortar required for each.—(General Gilmore, U.S.A.)*

MASONRY.	Volume of Mortar.	Lime required, no cement used.	Cement required, no lime used.	Difference of cost of Masonry with cement mortar and lime mortar.	COST. Lime mortar.	COST. Cement mortar.
	Cu. ft.	Bbls.	Bbls.	$ cts.	$ cts.	$ cts.
Rough, in rubble or gravel, from $\frac{1}{8}$ to $\frac{1}{10}$ cubic foot in volume,	10·8	·565	1·22	·90	4·10	5·
Blocks, large and small, not in courses; joints hammer-dressed,	8·1	·423	·92	·62	7·	7·62
Large masses; headers and stretchers dovetailed; hammer-dressed; beds and joints laid close,	1·	·05	·11	·08	9·	9·08
Ordinary; courses 20 to 32 in size,	1·5	·08	·17	·12	5·70	
Ordinary; courses 12 to 20 in size,	2·	1·05	·22	·16	2·19	
Brick,	8·	·42	·90	·66	5·70	6·20
Concrete, good,	11·	·54	1·75	1·21	2·19	3·20
" medium,	9·	·41	1·06	·65	1·56	2·21
" inferior,	8·	·37	·97	·60	1·45	2·05
Rubble, without mortar,					3· to 3·30	

Cost of materials assumed as follows: Cement, $1·20 per barrel; lime, $1; bricks, $4·25 per M; sand and gravel, 80 cents per ton; granite spalls, 55 cents per cubic yard; labor, $1 per day.

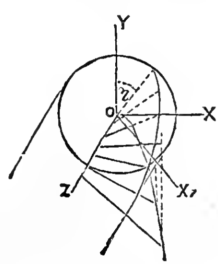
For walls less than 2 feet in thickness the cost is increased.

(To be continued.)

For the Journal of the Franklin Institute.

Intersection of the Joints of an Oblique Bridge with the Plane of the Face in the English System.

The joints* are warped surfaces subjected to the three conditions that the straight lines generating them shall pass through the axis, be perpendicular to it, and pass through helices drawn on the soffit.



The equations of this line then are $x = y$ tang v, $z] = z$, those of the helix are $x^2 + y^2 = r^2$, $z = c(v - \eta)$. The equation of the surface then (combining the above equations and eliminating v) is

$$z + c\eta = c \text{ tang}^{-1}\frac{x}{y}, \qquad . \qquad . \qquad . \qquad (1.)$$

The equations of the plane of the face are $z = ax$, y indeterminate. Combining this with the equation of the surface to determine their intersection, we have

* Vide Buck's Oblique Bridges.

its projection on XY, $ax + c\eta = c \text{ tang}^{-1} \frac{x}{y}$. Calling $\frac{a}{c} = b$, we have

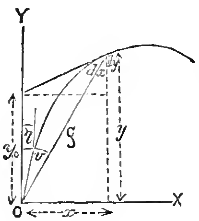
$$bx + \eta = \text{tang}^{-1} \frac{x}{y}, \quad . \quad . \quad . \quad . \quad . \quad (2.)$$

If we substitute $\text{tang}^{-1} \frac{x}{y} = v$, we have $bx + \eta = v$, from which the curve may be readily constructed; and since the increment of v is proportional to that of x, the curve is the quadratrix of Dinostratus.

If we wish the equation in the plane of the face, we readily obtain it by substituting $y = y_1$, $x = x_1$, cos a.

In equation (2) b evidently depends only on the form and dimensions of the arch, while η varies in the different joints.

Theorem.—In a given arch the subtangent for equal values of ρ is independent of the position of the joint, that is of η.

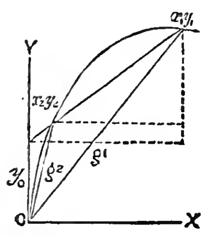


Proof. $\frac{dy}{dx} = \frac{y - y_0}{x}$ by similar triangles, or $y_0 = y - x\frac{dy}{dx}$, differentiating (2) we have

$$b\,dx = \frac{d\left(\frac{x}{y}\right)}{1 + \frac{x^2}{y^2}} = \frac{y\,dx - x\,dy}{y^2 + x^2}$$

multiplying out $by^2dx + bx^2dx = ydx - xdy$ or $x\frac{dy}{dx} = y - b\,(x^2 + y^2)$;

hence, $y_0 = y - x\frac{dy}{dx} = b\,(x^2 + y^2)$ or since the radius vector $\rho = \sqrt{x^2 + y^2}$,



$y_0 = b\rho^2$. This theorem is due to De la Gournerie who published a geometrical demonstration of it in the *Annales des Ponts et Chaussées*. It is practically applied thus: Since ρ is the same for all points of the intrados, calling this distance r, tangents to all the joints at the intrados intersect the axis of Y at br^2 from the origin.

Problem.—Is the intercept (on the axis of Y) of a line cutting the joint at ρ_1 and ρ_2 independent of η?

Solution.—Let x_1y_1, x_2y_2 be the co-ordinates of the points distant ρ_1 and ρ_2 from the origin. We have $\frac{x_1 - x_2}{y_1 - y_2} = \frac{x}{y_2 - y_0}$, multiplying out $x_1y_2 - x_1y_0 - x_2y_2 + x_2y_0 = x_2y_1 - x_2y_2$ or $y_0 = \frac{x_1y_2 - x_2y_1}{x_1 - x_2}$, but $x_1 = \rho_1 \sin v_1$, $y_1 = \rho_1 \cos v_1$, $x_2 = \rho_2 \sin v_2$, $y_2 = \rho_2 \cos v_2$, substituting

$$y_0 = \rho_1\rho_2 \frac{\sin v_1 \cos v_2 - \cos v_1 \sin v_2}{x_1 - x_2} = \rho_1\rho_2 \frac{\sin (v_1 - v_2)}{x_1 - x_2},$$

but since x_1y_1 and x_2y_2 are on the curve of the joint $v_1 = bx_1 + \eta$, $v_2 = bx_2$

$+\eta$; hence $y_0 = \rho_1 \rho_2 \frac{\sin b(x_1 - x_2)}{x_1 - x_2}$, calling $x_1 - x_2 = z$ we have

$$y_0 = \rho_1 \rho_2 \frac{\sin bz}{z}, \quad . \quad . \quad . \quad (3.)$$

since z evidently varies with η, that is, $x_1 - x_2$ is different for different joints; hence y_0 will vary. There is one exception, when z is infinitesimal or $x_1 - x_2 = dx$, since then $\frac{\sin bdx}{dx} = b$ independent of dx. This is evidently the case of the tangent, and as here $\rho_1 = \rho_2$, we have $y_0 = b\rho^2$ as previously proved.

Buck, in his work on oblique bridges, speaks of this problem, but does not attempt an analytical proof. He made the geometrical construction on a large scale, and found y_0 independent of η. His error arose from this, that in an ordinary bridge the pitch c of the spiral is very great, and $b = \frac{a}{c}$ very small; hence sin bz is so nearly equal to bz as to be indistinguishable in a drawing, and only becoming evident from the superior accuracy of analysis.

N. B. y_0 in practice is negative, but it is here taken positive for simplicity, as it does not alter the proofs.

MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

Work and Vis-viva. By De Volson Wood.

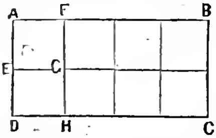
If I make any reply to the last article of Mr. Nystrom upon the subject under discussion, it must necessarily be upon some of the important points which I have previously omitted to discuss. I have no desire to mention them, for their *principles* are entirely foreign to our subject, and they are so elementary that it seems as if we ought not to be obliged to condescend to their discussion when treating of mechanical problems; but as I do not wish to be considered "unkind" on account of a partial treatment of the question, I will now notice them.

I have noticed several times that his views of multiplication are very different from mine, and it will be evident to the reader that one of us holds to views extremely faulty. For instance, he says, page 57, "When a quantity is multiplied by another quantity, the product becomes a third quantity, different from the two first." And again, "If two square feet be multiplied by a *thickness* of three linear feet, the product will be six cubic feet."

Now, I hold that, according to true logic, it is *impossible* to multiply one concrete number by another concrete number, and that every arithmetical process may be clearly analyzed without involving any such hypothesis. "But," says the objector, "do you not multiply linear

feet by linear feet to make square feet?" I say no, and proceed to analyze as follows:

To find the number of square feet in the rectangle A B C D, I have simply to find how many times it contains one square foot. We may form our unit by taking one foot from D on each of the lines A D and D C, and completing the square D E G H. Now, if A D is two linear feet, then will the rectangle A D H F contain *two times one square foot*, or two square feet. (Observe that it is TWO times, not TWO FEET *times*.) Then if A B contains four linear feet, the rectangle A C will



contain *four times two square feet*, or eight square feet. This is the logic, and nowhere have we multiplied linear feet by linear feet. So to get cubical contents, we commence with our cubical unit, which is one cubical foot or inch, as the case may be, and determine each time the *abstract* multiplier from the linear measure. This process is so evident that I need not dwell upon it. Admit that multiplication can be performed by addition, and we must admit that the *true multiplier* is an abstract number, and the product is of the same kind as the multiplicand. Hence, if *power* is correctly represented by a plane surface, and *time* by a straight line, and *work* by a volume, it appears that work is not the product of power by time; for if we multiply an area (power) by any number, (the *number of units* in the time,) we get an area for the result. But if power be correctly represented by a unit of volume, then a repetition of it will give another volume, or work.

Now, I do not object to the *illustrations* which he has made, if they are simply used to *represent* the things to the eye; but if they are made the basis of a logical argument, it should be shown that they have the same relation to each other as the things which they represent. Popularly speaking, the illustration is good, because we say in common language that length by breadth gives area, and area by thickness gives volume; but such is not the teaching of true science—of true logic.

So I do not wish Mr. Nystrom to infer, as he seems to on page 57, that when $T = 1$, time disappears from the formula. I do not wish it to. I cannot tell whether he wishes it to or not, for on page 326, vol. xlviii, he says at least twice in his own definition, that the unit of time is involved. It is implied on page 359 of the same volume. It is admitted on page 183, vol. xlix, when he says the English unit for power is 33,000 pounds raised one foot *per minute*; and in the three heterogeneous definitions which immediately follow the above, it may be inferred or denied at pleasure, while in his last article, page 57, he says, "Power $= F V \times 1$, *the abstract number.*" If, as Mr. Nystrom says, the products of two quantities becomes a third quantity different from the two first, will he give us a rule which will enable us to determine the nature or kind of this third quantity? If so, perhaps he can tell what the product will be of five cubic feet by three square feet; of ten hogs by five bushels of corn; of fifteen green pumpkins by ten ripe squashes.

For the Journal of the Franklin Institute.

Strength of Cast Iron and Timber Pillers: A series of Tables showing the Breaking Weight of Cast Iron, Dantzic Oak, and Red Deal Pillars. By Wm. Bryson, Civ. Eng.

Continued from vol. xlviii, page 349.

Solid Uniform Square Pillars of Dantzic Oak, both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Side of the square in inches.	Value of w in tons from formula $w=10\cdot95\frac{D^4}{L^2}$	Value of c.	Calculated breaking weight in tons from formula $Y=\frac{w\,c}{w+\frac{3}{4}c}$
6	11	4453·30	417·57	390·13
7	"	3271·81	"	383·87
8	"	2504·98	"	371·16
9	"	1979·24	"	360·52
10	"	1603·18	"	349·33
11	"	1324·95	"	337·74
12	"	1113·32	"	325·89
13	"	948·63	"	313·93
14	"	817·95	"	301·95
15	"	712·52	"	290 07
16	"	626·24	"	278·36
17	"	554·73	"	266·89
18	"	494·81	"	255·72
19	"	444·09	"	244·88
20	"	400·79	"	234·40
21	"	363·53	"	224·47
22	"	331·23	"	214·63
23	"	303·06	"	205·35
24	"	278·33	"	196·48
25	"	256·51	"	188·01
26	"	237·15	"	179·94
27	"	219·91	"	172·25
28	"	204·48	"	164·94
29	"	190·62	"	157·99
30	"	178·13	"	151·39

Solid Uniform Square Pillars of Dantzic Oak, both Ends being Flat and Firmly Fixed.

1	12	227059·2	496·94	496·12
2	"	56764·8	"	493·69
3	"	25228·8	"	489·70
4	"	14191·2	"	484·22
5	"	9082·36	"	477·35
6	"	6307·2	"	469·21
7	"	4633·87	"	459·94
8	"	3547·8	"	449·69
9	"	2803·2	"	438·62
10	"	2270·59	"	426·87
11	"	1876·52	"	414·59
12	"	1576·8	"	401·93
13	"	1343·54	"	389·02
14	"	1158·46	"	375·97
15	"	1009·15	"	362·90
16	"	886·95	"	349·90

(TABLE CONTINUED.)

Length or height of Pillar in feet.	Side of the square in inches.	Value of w in tons from formula $w=10{\cdot}95\frac{D^4}{L^2}$	Value of c.	Calculated breaking weight in tons from formula $y=\frac{wc}{w+\frac{3}{4}c}$
17	12	785·67	496·94	337·05
18	"	700·8	"	324·41
19	"	628·97	"	312·03
20	"	567·64	"	299·97
21	"	514·87	"	288·26
22	"	469·13	"	276·93
23	"	429·22	"	265·98
24	"	394·2	"	255·43
25	"	363·29	"	245·29
26	"	335·88	"	235·55
27	"	311·46	"	226·22
28	"	289·61	"	217·29
29	"	269·98	"	208·75
30	"	252·28	"	200·59
6	13	8687·30	583·21	555·25
7	"	6382·51	"	545·80
8	"	4886·60	"	535·29
9	"	3861·02	"	523·86
10	"	3127·42	"	511·65
11	"	2584·65	"	498·79
12	"	2171·82	"	485·44
13	"	1850·55	"	471·71
14	"	1595·62	"	457·73
15	"	1389·96	"	443·61
16	"	1221·65	"	429·44
17	"	1082·15	"	415·33
18	"	965·25	"	401·34
19	"	866·32	"	387·54
20	"	781·85	"	373·98
21	"	709·16	"	360·72
22	"	646·16	"	347·78
23	"	591·19	"	335·20
24	"	543·00	"	323·01
25	"	500·38	"	311·18
26	"	462·63	"	299·77
27	"	429·00	"	288·77
28	"	398·90	"	278·18
29	"	371·87	"	267·99
30	"	347·49	"	258·20

SOLID UNIFORM SQUARE PILLARS OF RED DEAL, BOTH ENDS BEING FLAT AND FIRMLY FIXED.

		$w=7{\cdot}81\frac{D^4}{L^2}$		
1	12	161948·16	423·36	422·53
2	"	40487·04	"	420·06
3	"	17994·24	"	416·01
4	"	10121·76	"	410·48
5	"	6477·92	"	403·57
6	"	4498·56	"	395·44
7	"	3305·06	"	386·25
8	"	2530·44	"	376·15

(TABLE CONTINUED.)

Length or height of Pillar in feet.	Side of the square in inches.	Value of w in tons from formula $w=7\cdot81\frac{D^4}{L^2}$	Value of *c*.	Calculated breaking weight in tons from formula $Y=\frac{w\,c}{w+\frac{3}{4}c}$
9	12	1925·28	423·36	363·42
10	"	1619·48	"	353·96
11	"	1338·41	"	342·18
12	"	1124·64	"	330·14
13	"	958·27	"	317·99
14	"	826·26	"	305·83
15	"	719·76	"	293·76
16	"	632·61	"	281·87
17	"	560·37	"	270·12
18	"	499·84	"	258·89
19	"	448·60	"	247·89
20	"	404 87	"	237·27
21	"	367·22	"	227·04
22	"	334·60	"	217·22
23	"	306·14	"	207·81
24	"	281·16	"	198·82
25	"	259·11	"	190·23
26	"	239·56	"	182·05
27	"	222·15	"	174·27
28	"	206·56	"	166·86
29	"	192·56	"	159·82
30	"	179·94	"	153·13

HOLLOW UNIFORM CYLINDRICAL PILLARS OF CAST IRON, BOTH ENDS BEING FLAT AND FIRMLY FIXED.

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	No. of diameters contained in the length or height.	Calculated breaking weight in tons from formula $w=46\cdot65\frac{D^{3\cdot55}-d^{3\cdot55}}{L^{1\cdot7}}$	Value of w.	Value of *c*.	Calculated breaking weight in tons from formula $Y=\frac{w\,c}{w+\frac{3}{4}c}$
8	3	2	32		51·26	192·42	50·43
9			36	41·96			
10			40	35·08			
11			44	29·83			
12			48	25·73			
13			52	22·46			
14			56	19·80			
15			60	17·61			
16			64	15·78			
17			68	14·23			
18			72	12·91			
19			76	11·78			
20			80	10·79			
21			84	9·93			
22			88	9·18			
23			92	8·51			

(TABLE CONTINUED.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	No. of diameters contained in the length or height.	Calculated breaking weight in tons from formula $W = 46 \cdot 65 \frac{D^{3 \cdot 55} - d^{3 \cdot 55}}{L^{1 \cdot 7}}$	Value of W.	Value of c.	Calculated breaking weight in tons from formula $Y = \frac{W c}{W + \frac{3}{4} c}$
24			96	7·92			
25			100	7·38			
8	4	3	24		119·40	269·39	100·06
9			27		97·73		87·82
10			30		81·70		77·56
11			33		69·48		68·93
12			36	59·93			
13			39	52·30			
14			42	46·11			
15			45	41·01			
16			48	36·75			
17			51	33·15			
18			54	30·08			
19			57	27·43			
20			60	25·14			
21			63	23·14			
22			66	21·38			
23			69	19·83			
24			72	18·44			
25			75	17·21			
8	5	4	19·2		225·43	346·36	160·92
9			21·6		184·52		143·84
10			24		154·26		129·04
11			26·4		131·19		116·22
12			28·8		113·15		105·09
13			31·2		98·75		95·40
14			33·6		87·06		86·94
15			36	77·43			
16			38·4	69·38			
17			40·8	62·59			
18			43·2	56·79			
19			45·6	51·80			
20			48	47·48			
21			50·4	43·70			
22			52·8	40·37			
23			55·2	37·44			
24			57·6	34·82			
25			60	32·49			
8	6	5	16		375·06	423·33	229·26
9			18		307·01		208·11
10			20		256·66		189·23
11			22		218·27		172·46
12			24		188·26		157·58
13			26		164·31		144·36
14			28		144·86		132·63
15			30		128·82		122 18
16			32		115·44		112·88
17			34	104·13			
18			36	94·49			
19			38	86·19			
20			40	78·99			

(TABLE CONTINUED.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	No. of diameters contained in the length or height.	Calculated breaking weight in tons from formula $W = 46.65 \frac{D^{3.55} - d^{3.55}}{L^{1.7}}$	Value of W.	Value of c.	Calculated breaking weight in tons from formula $Y = \frac{Wc}{W + \frac{3}{4}c}$
21			42	72·70			
22			44	67·18			
23			46	62·29			
24			48	57·94			
25			50	54·06			
8	7	5·5	13·714		782·50	721·58	426·56
9			15·428		640·51		391·11
10			17·142		535·48		358·87
11			18·857		455·38		329·72
12			20·571		392·77		303·45
13			22·285		342·80		279·82
14			24		302·22		258·56
15			25·714		268·77		239·44
16			27·428		240·84		222·22
17			29·142		217·25		206·69
18			30·857		197·14		192·67
19			32·571	179·82			
20			34·285	164·81			
21			36	151·69			
22			37·714	140·15			
23			39·428	129·95			
24			41·142	120·89			
25			42·857	112·78			
8	8	6·5	12		1139·76	837·03	539·73
9			13·5		932·94		500·34
10			15		779·95		463·75
11			16·5		663·29		430·02
12			18		572·09		399·09
13			19·5		499·30		370·81
14			21		440·20		345·01
15			22·5		391·48		321·49
16			24		350·80		300·06
17			25·5		316·44		280·51
18			27		287·15		262·70
19			28·5		261·92		246·41
20			30		240·05		231·53
21			31·5		220·94		217·89
22			33	204·14			
23			34·5	189·28			
24			36	176·08			
25			37·5	164·27			
8	9	7·5	10·666		1582·15	952·49	656·16
9			12		1295·06		613·87
10			13·333		1082·68		573·85
11			14·666		920·74		536·35
12			16		794·14		501·43
13			17·333		693·11		469·31
14			18·666		611·06		439·35
15			20		543·44		411·52
16			21·333		486·97		386·10
17			22·666		439·27		362·68

(TABLE CONTINUED.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	No. of diameters contained in the length or height.	Calculated breaking weight in tons from formula $W=46{\cdot}65\frac{D^{3{\cdot}55}-d^{3{\cdot}55}}{L^{1{\cdot}7}}$	Value of W.	Value of c.	Calculated breaking weight in tons from formula $Y=\frac{W\,c}{W+\frac{3}{4}c}$
18			24		398·61		341·13
19			25·333		363·59		321·27
20			26·666		333·23		302·97
21			28		306·71		286·10
22			29·333		283·38		270·52
23			30·666		262·76		256·13
24			32		244·42		242·81
25			33·333	228·04			
8	10	8·5	9·6		2115·61	1067 94	774·65
9			10·8		1731·70		730·20
10			12		1447·74		687·55
11			13·2		1231·19		647·01
12			14 4		1061·91		608·76
13			15·6		926·81		572·86
14			16·8		817·10		539·29
15			18		726·67		508·00
16			19·2		651·16		478·88
17			20·4		587·38		451·82
18			21·6		533·01		426·71
19			22·8		486·19		403·38
20			24		445·58		381·73
21			25·2		410·12		361·64
22			26·4		378·93		342·97
23			27·6		351·36		325·63
24			28·8		326·84		309·53
25			30		304·93		294·46
8	11	9	8·727		3449·00	1539·38	1153·31
9			9·818		2823·16		1092·57
10			10·909		2360·19		1033·71
11			12		2007·16		977·25
12			13·090		1731·18		923·49
13			14·181		1510·94		872 60
14			15·272		1332·08		824·64
15			16·363		1184·66		779·60
16			17·454		1061·56		737·39
17			18·545		957·58		697·91
18			19·636		868·95		661·06
19			20·727		792·61		626·62
20			21·818		726·42		594·50
21			22·909		668·60		564·53
22			24		617·76		536·57
23			25·090		572·80		510·47
24			26·181		532·83		486·10
25			27·272		497·12		463·32
8	12	10	8		4392·96	1693·32	1313·57
9			9		3595·83		1251·35
10			10		3006·15		1190·41
11			11		2556·51		1131·31
12			12		2205·00		1074·46
13			13		1924·47		1020·12
14			14		1696·66		968·42

(TABLE CONTINUED.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in in inches.	No. of diameters contained in the length or height.	Value of w in tons from formula $w = 46{\cdot}65\frac{D^{3\cdot55} - d^{3\cdot55}}{L^{1\cdot7}}$	Value of c.	Calculated breaking weight in tons from formula $Y = \frac{w\,c}{w + \frac{3}{4}c}$
15			15	1508·90	1693·32	919·45
16			16	1352·10		873·17
17			17	1219·66		829·54
18			18	1106·77		788·51
19			19	1009·55		749·92
20			20	925·23		713·69
21			21	851·60		679·69
22			22	786·84		647·77
23			23	729·57		617·83
24			24	678·67		589·74
25			25	633·18		563·36
8	13	11	7·384	5479·02	1847·26	1474·43
9			8·307	4484·82		1411·28
10			9·230	3749·36		1348·84
11			10·153	3188·55		1287·73
12			11·076	2750·13		1228·41
13			12	2400·26		1171·22
14			12·923	2116·12		1116·36
15			13·846	1881·94		1063·98
16			14·769	1686·38		1014·11
17			15·692	1521·20		966·76
18			16·615	1380·40		921·94
19			17·538	1259·14		879·51
20			18·461	1153·98		839·44
21			19·384	1062·14		801·62
22			20·307	981·37		765·94
23			21·230	909·95		732·30
24			22·153	846·46		700·58
25			23·076	789·72		670·67
8	14	12	6·857	6715·87	2001·19	1635·64
9			7·714	5497·24		1571·99
10			8·571	4595·74		1508·52
11			9·428	3908·34		1445·92
12			10·285	3370·96		1384·67
13			11·142	2942·10		1325·16
14			12	2593·82		1267·66
15			12·857	2306·78		1212·37
16			13·714	2067·07		1159·37
17			14·571	1864·60		1108·72
18			15·428	1692·01		1060·48
19			16·285	1543·38		1014·56
20			17·142	1414·48		971·37
21			18	1301·91		929·55
22			18·857	1202·91		890·32
23			19·714	1115·36		853·14
24			20·571	1037·54		817·95
25			21·428	967·99		784·61
8	15	12·5	6·4	9700·51	2645·81	2196·47
9			7·2	7940·29		2116·78
10			8	6638·17		2036·89
11			8·8	5645·27		1957·65

(TABLE CONTINUED.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	No. of diameters contained in the length or height.	Value of W in tons from formula $W = 46·65 \frac{D^{3·55} - d^{3·55}}{L^{1·7}}$	Value of *c*.	Calculated breaking weight in tons from formula $Y = \frac{W c}{W + \frac{3}{4} c}$
12	15	12·5	9·6	4869·06		1879·71
13			10·4	4249·61		1803·59
14			11·2	3746·56		1729·66
15			12	3331·94		1658·21
16			12·8	2985·71		1589·41
17			13·6	2693·26		1523·37
18			14·4	2443·97		1460·18
19			15·2	2229·28		1399.77
20			16	2043·10		1342·17
21			16·8	1880·50		1287·33
22			17·6	1737·51		1235·14
23			18·4	1611·05		1185·52
24			19·2	1498·64		1138·39
25			20	1398·18		1093·62
8	16	13·5	6	11594·01	2838·23	2397·96
9			6·75	9490·21		2318·24
10			7·5	7933·91		2237·82
11			8 25	6747·20		2157·54
12			9	5819·49		2078·09
13			9·75	5079·12		2000·01
14			10·5	4477·87		1923·73
15			11·25	3982·33		1849·57
16			12	3568·51		1777·76
17			12·75	3218·97		1708·45
18			13·5	2921·03		1641·79
19			14·25	2664·43		1577·73
20			15	2441·90		1516·36
21			15·75	2247·56		1457·66
22			16·5	2076·66		1401·56
23			17·25	1925·52		1348·00
24			18	1791·12		1296·90
25			18·75	1671·10		1248·22
8	17	14·5	5·647	13697·25	3030·66	2599·31
9			6·354	11211·80		2519·81
10			7·058	9373·18		2439·16
11			7·764	7971 20		2358·21
12			8·470	6875·16		2277·64
13			9·176	6000·52		2198·04
14			9·882	5290·19		2119·84
15			10·588	4704·75		2043·42
16			11·294	4215·87		1969·04
17			12	3802·92		1896·89
18			12·705	3450·92		1827·17
19			13·411	3147·78		1759·87
20			14·117	2884·88		1695·09
21			14·823	2655·29		1632·87
22			15·529	2453·38		1573·16
23			16·235	2274·82		1515·93
24			16·941	2116·10		1461·16
25			17·647	1974·25		1408·74
8	18	15·5	5·333	16017·99	3223·08	2800·45

(TABLE CONTINUED.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	No. of diameters contained in the length or height.	Value of W in tons from formula $W = 46{\cdot}85 \frac{D^{3\cdot55} - d^{3\cdot55}}{L^{1\cdot7}}$	Value of *c*.	Calculated breaking weight in tons from formula $Y = \frac{W c}{W + \frac{3}{4} c}$
9			6	13111·43		2721·35
10			6·666	10961·29		2640·71
11			7·333	9321·76		2559·38
12			8	8040·05		2478·03
13			8·666	7017·19		2397·26
14			9·333	6186·51		2317·53
15			10	5501·88		2239·24
16			10·666	4930·17		2162·69
17			11·333	4447·25		2088·09
18			12	4035·62		2015·69
19			12·666	3681·11		1945·50
20			13·333	3373·67		1877·68
21			14	3105·18		1812·27
22			14·666	2869·06		1749·25
23			15·333	2660·25		1688·64
24			16	2474·63		1630·42
25			16·666	2308·75		1574·52

(To be continued.)

On Chemistry Applied to the Arts. By Dr. F. Crace Calvert, F.R.S., F.C.S.

From the London Chemical News, No. 243.

(Continued from page 114.)

Lecture IV.

Animal Fatty Matters, the various processes for liberating them from the tissues in which they are contained. Their composition and conversion into soap. Composite candles. The refining of lard. *Cod liver*, *Sperm*, and other oils. *Spermaceti* and *wax*.

It will be quite out of the question for me to enter upon a general description of the properties and composition of fatty matters, as to do so would be to undertake far too wide a field of research. All that I can attempt in this lecture is to give an idea of their composition, and to describe some of their most recent applications to arts and manufactures.

The question of the source of the fatty matters in herbiverous animals has been the subject of a great number of scientific researches, but those of Baron Liebig, Dumas, Boussingault, Payen, and Milne Edwards have left no doubt that when the food of an animal contains a sufficient amount of fatty matter, this is simply extracted from the

food, and stored or consumed according to the animal's habits; that is to say, its consumption is in ratio to the activity of the animal; thus, an animal in a state of great activity is comparatively thin, but when confined in a pen or stall it quickly fattens. These gentlemen also proved that when the food is deficient in fatty matters, a portion of the amylaceous or saccharine matter becomes converted into fatty matter. The most decisive experiments on this head were made by Mr. Milne Edwards, who found that when bees were confined under a glass shade, with no food but honey, they converted the greater portion of it into wax. Notwithstanding these proofs, however, chemists found it difficult to understand how substances so rich in oxygen as amylaceous ones becomes converted into a class of matters containing so little of that element, but Baron Liebig has lately published a paper which has partially solved this problem, showing that animals give off during respiration a larger amount of oxygen than is contained in the air inspired, which excess must be derived from certain organic substances circulating in the blood. Fatty matters may be classed under two heads, viz: vegetable and animal. The first are generally composed of a solid called margarine, and a liquid called oleine. The latter generally contains three substances, viz: two solids, stearine and margarine, and one liquid, oleine. I say generally, because their are exceptions: thus, in palm oil palmetine is found, in linseed oil, linoleine, in sperm oil, spermaceti, and in waxes several peculiar acids. Let us now examine the composition of some of the most abundant fatty matters found in animals. The knowledge of the composition of these substances, of suet for example, was most unsatisfactory until 1811, when my learned and eminent master, M. Chevreul, published his elaborate researches, by which he demonstrated the real composition of fatty matters in general, and that they might be considered as real organic salts. Thus, suet is composed of stearic, margaric, and oleic acid combined with the oxide of glyceryle. The three above-named acids he showed to be composed as follows:

	Stearic acid.	Margaric acid.	Oleic acid.
Carbon, . . .	68	34	36
Hydrogen, . . .	66	33	33
Oxygen, . . .	5	3	3
Water, . . .	2	1	1

Also that oxide of glyceryle, as it is liberated from the fatty acids, combines with water and forms glycerine. He further showed that when fatty matters were saponified, the change consisted in the substitution, for the oxide of glyceryle, of the oxide of sodium or soda in ordinary hard soaps, of the oxides of potassium and potash in soft soaps, of oxide of lime, baryta, or lead in insoluble soaps. You will easily conceive the pride of M. Chevreul when, forty years later, M. Berthelot effected the synthesis of the fatty matters, the analysis of which M. Chevreul had published in 1811. This he accomplished by heating in sealed tubes, at a temperature of 520° for several hours, one, two, or three equivalents of each of the above acids, with one equivalent of glycerine, leaving the mixture to cool, and then boiling

it in a vessel with water and lime, when the excess of fatty acids not combined during the experiment were removed by the lime, leaving the neutral fatty matter, which was dissolved by ether, ahd thus obtained in a state of purity. By this interesting series of researches, M. Berthelot has not only reconstituted neutral fatty matters, but showed that the oxide of glyceryle was triatomic; that is, that one equivalent of the oxide would neutralize three equivalents of the acid, whilst it required three equivalents of soda to produce a neutral stearate with three equivalents of stearic acid.

Stearic acid, $3\,(C_{68}H_{66}O_5)$ Glycerine, $C_6H_8O_6$—4 HO.

Stearic acid, $3\,(C_{68}H_{66}O_5)$+Soda, NaO—3 HO.

In fact, the researches of this eminent chemist on the synthesis of organic substances have effected a complete revolution in the last few years in that branch of organic chemistry.

I shall now proceed to give you a rapid outline of the properties of these substances.

Stearic acid is a white crystalline substance, fusible at 158° F., soluble in alcohol and ether, insoluble in water, and saponified by alkalies.

Margaric acid is a solid crystalline substance, presenting the same properties as stearic, excepting that its fusing point is 140°.

Oleic acid is a fluid remaining in that state even at several degrees below the freezing point of water, and is also soluble in alcohol and ether, but not in water.

Glycerine, or the sweet principle of oils, was discovered in 1779, by Scheele, who extracted it in boiling oil of sweet almonds with oxide of lead, which, combining with the fatty acids, liberated the oxide of glyceryle, and this, in combining with water, formed glycerine. In consequence of the numerous applications of glycerine in medicine, the French have manufactured this substance on a large scale from the liquors in which they have saponified their fatty matters into soap; but the purest and most extensive supply is furnished by Price's Patent Candle Company. In the course of this lecture I will give you a description of its preparation as carried out at their works. Glycerine is a colorless, syrupy fluid, of sweet taste, and sp. gr. 1·28, highly soluble in water and alcohol, combining easily with hydrochloric, hydrobromic, benzoic, tartaric, &c., acids, forming neutral compounds. Diluted nitric acid converts it into glyceric acid; concentrated nitric acid into nitro-glycerine, or a substance exploding with violence by percussion, which has caused it to be proposed as a substitute for fulmintaing mercury by its discoverer, Professor Sobrero. The application in medicine of glycerine has been greatly extended by its highly hygrometric properties. Thus, bandages moistened with glycerine remain constantly moist, because the glycerine attracts moisture from the air as fast as it is lost by evaporation. It has also been found eminently useful in diseases of the eye and ear. Glycerine boils at 527°, but when distilled is partly decomposed into a peculiar oily fluid, of a noxious odor, called acroleine. M. Berthelot has succeeded, by fermentation, in converting glycerine into alco-

hol. Again, Mr. George Wilson, F.R.S., the talented director of Price's Patent Candle Company, has applied glycerine, with great success to the preservation of vegetable and animal substances. Another useful employment of glycerine is its substitution for water in gasometers, where the evaporation of the latter is a source of serious loss. Its addition to a soap solution increases the facility of forming soap bubbles to an extraordinary degree. In fact, by its aid bubbles of seven or eight inches diameter can be produced, exhibiting most beautiful purple and green colors, the beauty of which is greatly enhanced, as Mr. Ladd will show you, when illuminated by the electric light. To prepare this peculiar soap solution, the following proportions are stated to be employed: Distilled water, 5 ounces; soap $\frac{1}{8}$ of a drachm; glycerine, 2 drachms.

The extraction of the fatty matters of animals from the tissues enveloping them is a simple operation. The old process of doing this, technically called "rendering," consisted in introducing the suet into large iron pans and applying heat, which caused the fatty matters, by their expansion, to burst the cells confining them, and to rise to the top of the contents of the boiler, which were left to stand for a few hours, and the liquid fat was then run off. The organic tissues remaining with a certain amount of fat at the bottom of the boilers were removed and subjected to pressure so as to separate the rest of the fat, the organic tissues remaining behind being sold under the name of scraps for feeding dogs, &c. As this operation gives rise to noxious vapors, causing thereby great annoyance, other methods have been generally adopted. For instance, Mr. D'Arcet's, the leading feature of which is to place in a boiler say 350 ℔s. of suet, with 150 of water, 15 of sulphuric acid, carrying the whole to the boil for some hours, when the sulphuric acid dissolves the organic matters and liberates the fatty ones, which are then easily separated from the aqueous fluid. Mr. Evrard's process appears preferable. He boils the fatty matters with a weak solution of alkali; or, in other words, he uses 300 ℔s. of suet with half a pound of caustic soda dissolved in twenty gallons of water, carrying the whole to the boil by means of a jet of steam. Under the influence of the alkali the tissues are swollen and dissolved and the fat liberated. By these operations a better quality of fat is obtained and no nuisance is created. It is found advantageous to purify or bleach the above fatty matters by the following means. Mr. Dawson's process consists in passing air through the melted tallow, and Mr. Watson's in heating melted fatty matter with permanganate of potash. Both these processes, as you will perceive, are based on the oxidation of the coloring organic matter. Some tallow melters further clarify their tallow by adding 5 ℔s. of alum in powder to 100 ℔s. of melted tallow, which separates and precipitates any coloring matter. The white snowy appearance of American lard, which is rather deceptive to the eye than profitable, is obtained by thoroughly mixing by means of machinery, starch in a state of jelly with a little alum and lime, with the fatty matter, by which means two ends are attained—viz; the introduction of 25 per cent. of useless matter, and a perfect white-

ness from the high state of division of the same. The fatty matters from fish are generally obtained by boiling those parts of the fish containing them with water, when the fatty matters rise to the surface of thefluid, and one whale has been known to yield as much as a 100 tons of oil. According to M. Chevreul, the composition of whale oil is as follows:

Solid fats, ...	Margarine, Cetine.
Liquid fats, ...	Oleine, Phocènine.

together with a small amount of coloring matter, and of phocenic acid, which gives to whale oil its disagreeable color and odor. Many attempts have been made to sweeten whale oil by the use of weak caustic lye, milk of lime, sulphuric acid, and steam; but although a great improvement has been effected, the oil is still recognisable by its unpleasant odor. I have no doubt in my mind, from experiments made by my friend Mr. Clift, that fish oils might be obtained as sweet as vegetable oils, if proper means for their extraction were adopted. Allow me here to revert to animal fats, to show you that their comparative hardness or solidity, as shown by the following table, depends upon their relative proportions of stearine and margarine, or oleine:

	Stearine or Margarine.	Oleine.	Melting point.
Ox tallow, . .	75	25	111·0°
Mutton suet, . .	74	26	109·0
Hog's lard, . .	38	62	80·5
Butter (summer), .	40	60	86·2
Do. (winter), .	63	57	79·7
Goose fat, . .	32	68	79·0
Duck fat, . .	28	72	77·0

M. Pelouze proved some years ago that the rancidity of ordinary animal as well as vegetable oils is due to a fermentation; that is to say, that under the influence of the azotised principle associated with all fats, the fatty matters split into their respective fatty acids and glycerine, which in their turn undergo a further change, resulting in the production of volatile fatty acids, such, for example, in the case of butter, as butyric, caproic, capric, and caprolic acids; in the case of goat's milk, hirsic acid; of fish oil, phocenic acid. Further, M. Pelouze demonstrated that in the case of olive oil this change occurred a few hours after the crushing of the berries, the oil thereby coming in contact with the albuminous principles or ferment.

I shall now have the pleasure of calling your attention to some of the special applications which fatty matters receive. The first of these arises out of the action of alkalies upon these substances, the result of which is the conversion of an insoluble matter (oil) into a soluble one (soap). I shall not enter into minute details of this well known manufacture, but content myself with touching upon some of the most recent improvements. The usual mode of making soap is to add animal fats or vegetable oils to a weak lye, or caustic solution, carrying the mixture to the boil by means of steam pipes passing through the vessel above a false bottom, and keeping the whole in constant

agitation by means of machinery. During this operation the oxide of sodium replaces in the fatty matter the oxide of glyceryle, and when the lye is killed, that is to say when all its alkali is removed by the oil, a fresh or stronger lye is added, and these operations are repeated until the manufacturer considers that the matter is nearly saponified, which is easily judged of in practice. He then proceeds with a second series of operations, called salting, which have for their object to separate the glycerine and impurities from the soapy mass, and also to render the latter more firm and compact, in fact, to contract it. This is effected by treating it with stronger lye mixed with a certain quantity of common salt, and allowing it to stand for a few hours, so that the mass of soap may separate from the fluid containing glycerine, and other impurities. When the second series of operations are finished the clarifying or finishing process follows: this requires the use of still stronger lye and salt, which not only complete the saponification, but separate any remaining impurities; the semifluid mass of soap is then allowed to stand for twelve hours, when the soap is either run or ladled into large wooden moulds, and allowed to stand until quite cold. After standing for a day or so, the wooden frame is removed from the solid mass of soap, when it is divided into bars by means of a brass wire. The difference between *white curd* and *mottled* soap is caused by the addition to the fluid mass of soap of about four ounces of alum and green copperas to every 100 lbs. of soap, which gives rise to an alumina and ferruginous soap, which, on being diffused through the mass by means of agitation, mottles or marbles the mass when cool. When well prepared this is the most economical soap, as no large quantity of water can be introduced to weight it, because this would cause the separation of the mottling material from the soap. *Fancy soaps* are prepared in the above manner by the employment of a better quality of materials and the addition of various perfumes. *Rosin or yellow soap*, as its name implies, is one in which a portion of the fatty matters is replaced by rosin, which is added to the soap paste when there is but little aqueous solution of alkali left to dissolve it, so that the rosin can at once enter into the composition of the soap, instead of being dissolved in the alkaline lye and lost. Rosin soaps, nearly white, are now manufactured, owing to the discovery of Messrs. Hunt and Pochin, who have succeeded in obtaining nearly white rosins by distilling common rosin with the aid of superheated steam. *Silicated soaps* are much used in America, owing to their cheapness, which is due to the introduction of a certain amount of silicate of soda. *Transparent soap*, the method of making which was so long kept secret, is now known to be obtained by dissolving soap in alcohol and allowing a concentrated solution of it to cool slowly, when it is poured into moulds and allowed to solidify. One of the most useful and recent improvements in soap making is that which enables the manufacturer to produce what is called *glycerine soap*, which is characterized by the retention of the glycerine of the fatty matter. Its manufacture only occupies a few hours, instead of several days, as is the case with ordinary soap. It is prepared by employing 63 parts of fatty matter, 33

of water, and 5 of alkali, which are heated to a temperature of between 350° and 400°, for two or three hours, when the mass is entirely saponified, and then has only to run into moulds to be ready for the market. But the most important discovery connected with the saponification of fatty matters by means of alkali is that recently made by M. Mèges Mouries, for this gentleman has arrived at the remarkable result of saponifying fatty matter in the space of twelve hours, and, what is more extraordinary still, at natural temperatures. If we connect this fact with the one that caustic soda is now manufactured by tons, it appears highly probable that in a few years the fatty matters of Brazil and Monte Video, instead of being sent to this country as such, will be converted into soap there, and imported thence by us in that form. M. Mouries has discovered the fact that fatty matters are susceptible, under peculiar circumstances, of being brought into a globular state, and that when in that state they present new and peculiar properties. Thus, for example, fatty matters, when kept in a damp state, usually become rapidly rancid, whilst when in the globular state they may be kept for a very long period without undergoing that change. This peculiar state can be imparted to fatty matters by melting them at 130° and adding a small quantity of yolk of egg, bile, albuminous substances, or, what is best, a solution of alkali, composed of five to ten parts of alkali for every 100 parts oil, at the same temperature, agitating the whole for some time to bring the fatty matter into a globular condition. If at this stage the action of the alkali is continued and the temperature is raised to 140°, it is found that instead of the fatty matters requiring a long time to saponify, (as is usual even at a temperature of 212°,) the saponification is most rapid, because each globule of fatty matter offers an immense surface to the action of the alkali; and it is found that in two or three hours the whole of the fatty matters are converted into soap. In fact, saponification is so perfect that the mass of soap dissolves completely in water; and if the purpose is to liberate the fatty acids, this can be done at once by the addition of a little vitriol. The fatty acids produced by this comparatively cold saponification are so pure that, when subjected to pressure, the solid fatty acids have not the slightest odor, and fuse at the point of 138°. As to the oleic acid prepared by this process, instead of being brown, (as is usual with the commercial acid,) it is colorless and can be employed in manufacturing soap of good quality. When M. Mouries desires to make soap with the entire fatty matter, he acts at once upon the globular fatty mass by adding salt, which separates the soap from the aqueous fluid; it is then melted and run into moulds. Whilst speaking of the mode in which alkalies can be made to act upon fatty matters, I ought to state that M. Pelouze observed the curious fact that large quantities of fatty matters could be split into their respective elements, viz: fatty acids and glycerine, by heating them for some hours with a small quantity of soap. This discovery, as we shall presently see, has been taken advantage of in the manufacture of stearic candles.

Permit me to state that *soft soaps* differ from hard soaps mainly in

the substitution of potash for soda, and in the omission of the salting and clarifying processes, so that the soapy mass is not separated from the excess of water, and therefore after the fatty matter has been saponified by the alkali, the whole is evaporated to the required consistency. I cannot conclude better this hasty and imperfect sketch of the soap manufacture than by the following table of compositions, showing the per centages of the various elements in the following soaps:

Names of soaps.	Fatty acids.	Alkali.	Water.
Curd, . . .	62	6·0	32·0
Marseilles, . .	60	6·0	34·0
White, . . .	60	6·4	33·6
White cocoa, . .	22	4·5	73·5
Yellow rosin, . .	70	6·5	23·5
Calico printer's, .	60	5·2	34·8
Silk boiling, . .	57	7·0	36 0
Wool scouring, .	55	9·0	36·0
Soft, . . .	43	10·0	47·0
Theoretical, . .	63	6·4	30·6

As it is easy to introduce into soaps a much larger quantity of water than they should contain to render their employment economical, it behooves those which use large quantities in their manufacture to ascertain the extent of the moisture contained in soaps. This may be pretty accurately approximated to, by placing a quarter of an ounce, divided into thin shreds, upon a hob or other warm situation, and leaving it for several days, when it will lose nearly the whole of the water it originally contained, or about a third of its weight, if it does not contain an undue proportion. In many instances the proportions of alkali in soap may seriously affect its applicability. Thus I ascertained a few years since that the quality of soap best adapted to clear madder purples should not contain more than 5 per cent. of alkali, whilst for pinks, where it is necessary to remove any loose color which the mordants may have mechanically retained, a more active soap is required, viz: one containing from 6 to 7 per cent. of alkali.

(To be continued.)

For the Journal of the Franklin Institute.

Speed of Ships.

The brig *Los Amigos*, Captain Johnson, has made the run from Belize, Honduras, to the Port of New York in 14 days.

The brig *Nellie Antrim*, Captain Wallace, arrived at the port of New York, evening July 11, 1865, having made the round voyage out to Nuevitas and back, with a full cargo each way, in 30 days' time.

The clipper ship *Twilight*, Captain Holmes, left New York December 24, 1864, and arrived at San Francisco April 20, 1865, making the voyage at that season of the year in the short time of 117 days.

The steamer *Guiding Star*, Captain Berry, belonging to the New York Mail Steamship line, arrived at the port of New York Friday

July 28, 1865, having made the run from New Orleans in 5 days, 11 hours, and 30 minutes, the quickest passage on record between these two ports.

The steamer *Morro Castle*, Captain ——, and owned by Messrs. Spafford, Tileston, & Co., arrived at the port of New York July 5, 1865, having made the run from Havana in the remarkable time of 3 days and 15 hours. E.M.B.

On the Supposed Nature of Air prior to the Discovery of Oxygen.

By George F. Rodwell, F.C.S.

From the London Chemical News, No. 279.

Continued from vol. xlix, page 406.

XI. *Rise of Scientific Societies.*—Inasmuch as in the following papers we shall have frequently to allude to the labors of various scientific societies in connexion with the subject under consideration, and as, moreover, institutions of this nature have done much to further the progress of experimental philosophy, I conceive it will not be out of place here to give a short account of their rise, and of their effect on the progress of physical science.

Among the ancients there was no experimental philosophy; we read of a few isolated experiments—such as the electrical experiment of Thales, the proof of the materiality of air proposed by Anaximenes, and the magnetic experiment mentioned by Lucretius—but these were exceptions; men preferred to rely on the unaided intellect rather than to call in assistance from external sources; they preferred to give a theoretical explanation of a natural phenomenon, and to reason on that, all unproven as it was, as if it were a well established and absolute truth. Let any one read the "Physics" of Aristotle if he wishes to comprehend the tone of physical thought which prevailed among the ancients. Such a treatise is intolerable to a follower of the Baconian method; the long, dreary trains of reasoning, perpetually ramifying in all directions, and the continued proposal of one theory to support another, so divert the mind from the subject discussed, that it ultimately grasps the explanation with difficulty. Such a system has no solid basis; destroy one theory in any part of the explanation, and the whole mass of reasoning in a moment falls to the ground. When we remember that this was the scientific text-book for 2000 years, can it be wondered that the physical sciences are now almost new-born in the world?

Passing onward to this side of the Christian era, we find a manifest lessening of intellectual activity; the golden age of literature among the ancients had passed away. Greece for a long period had ceased to furnish writers of eminence; the Romans, tired of conquest, became indolent, luxury and corruption followed, and, as a consequence, enervation of intellectual power. Then came those uncivilized Northern races, which, in destroying the Roman empire, at the same time crushed all traces of learning; but that unyielding besom, while it

swept away a debased and impoverished literature, did also remove the causes which had conduced to its impoverishment.

From the time of the destruction of the Roman empire till the fifteenth century, science, in common with all other pursuits depending on mental energy, was utterly neglected. There could be but little learning during the Middle Ages. The priests were the most educated members of the community, and on that account they possessed immense power over the human mind, for on them devolved not only spiritual but also temporal teaching. But they were an ignorant class of men, and cared for nought but to uphold and maintain the dominion of their Church, and their own dominion over the minds of men. Their could be no scientific progress; for had not that Church, now dominant and supreme, condemned the study of physical science? had it not affirmed that the Aristotelian philosophy was sufficient for all purposes, and ruled that it alone should be followed? In the fifteenth century the power of the Church began to wane; Savonarola had arisen, and had waged war against the obsolute dominion of the hierarchy; Sarpi was soon to appear; a few had ventured to dispute the authority of Aristotle in physical matters, and had been punished for their freedom of thought. The human mind began to arouse itself after its long imprisonment, and to strive to burst asunder its fetters, for the Church had at first bound it captive with silken threads easy to be broken, but eventually they became fetters of steel. A yearning for intellectual progression was apparent, a desire to employ the long neglected attribute of reason; and now in that land in which more than a thousand years before learning had been almost blotted out, there arose a regenerated intellect—a new tone of thought; Italy was the cradle in which it gained vigor, and it passed out thence to civilize the whole world.

Among the greatest experimental philosophers of the Middle Ages, I may mention Roger Bacon,* Albertus Magnus, the Spanish philosopher Averröes, and Leonardo da Vinci. We may briefly refer to the first and last of these.

The sixth part of Bacon's "Opus Majus"† bears the title "De Scientia Experimentalis." The first chapter treats "of the utility of experimental science;" the last "of the dignity of the experimental arts." Throughout the work we find a strong advocacy of experiment as a guide to the intellect to assist it in arriving at the causes of unusual physical effects. No treatise at all comparable to this appeared during the Middle Ages—indeed, not until the publication of the "Novum Organum."

Leonardo da Vinci‡ is known to every one as a great painter, but it is not so generally known that he was a great mathematician, physicist, and engineer, and by no means an inferior musician. His phy-

* Born, 1214. Died, 1284.

† "Fratris Rogeri Baconis, Opus Majus." Ad Clementum Quartum. Ex M. S. Codice Dubliniensi cum aliis quibusdam collato, nunc primum edidit S. Jebb, M. D. Londini. 1733.

‡ Born, 1452. Died, 1519.

sical views are far in advance of those of either his own or the succeeding age; our chief knowledge of them is derived from some of his unpublished MSS., which are preserved in the King's library at Paris; many of these were translated into French by Venturi, and published in 1797.*

The following passage is written in the true spirit of inductive philosophy; indeed, no one who has read the "Novum Organum" can fail to be reminded of many of the similar passages therein:

"*Of Method.*—Theory is the general, practice the soldiers. The interpreter of the artifices of Nature is experiment. It never deceives; it is our judgement that sometimes deceives itself, because it expects results which experiment refuses. We must consult experiment, varying the circumstances until we have deduced general rules, for it alone can furnish reliable rules. But you ask me, Of what advantage are these rules? I answer that they guide us in the researches of Nature, and the operations of art. They prevent us from deceiving ourselves or others by promising ourselves results which we cannot obtain."

I may also mention a sentence bearing directly on our subject, in which we have proof of most advanced physical knowledge for the period, and which shows that Leonardo da Vinci was aware that fire is not elemental, and that it requires air for its sustenance—a theory, I need not say, wholly at variance with that maintained by his contemporaries:

"*Of Flame and Air.*—There is smoke in the centre of the flame of a wax candle, because the air which enters into the composition of the flame cannot penetrate to the middle of it. It stops at the surface of the flame, and condenses there; in becoming aliment of the flame, it is transformed into it, and leaves a void space which is filled successively by other air."

In the middle of the sixteenth century the Church armed itself with a new and powerful weapon to suppress free thought; this was the right which it assumed of prohibiting the printing and reading of certain books which were believed to inculcate injurious ideas. The first catalogue of prohibited books was published by Paul IV. in 1559. In it no less than sixty-one printers were condemned, and *all* works issuing from their presses were forbidden to be read. Theological treatises were not the only works submitted to examination; scientific works did not escape. Thus I find at the commencement of Baptista Porta's four books "De Aëris Transmutationibus," an order from the examiner allowing them to be printed, because, he writes, "in quibus nihil inveni, quod sit contra fidem, aut bonos mores."†

* "Essai sur les ouvrages physico-mathematiques de Leonard da Vinci, avec des fragmens tirés de les manuscrits." Par J. B. Venturi. Paris. An v. (1797.)

† The order is conveyed in the following form:

"Imprimatur, si videbitur R. P. M. Sacri. Pal. Apost.

"Cæsar Fidelis Vices-gerens.

"Iussu Reurendissimi P. F. Ludouici Ystella Sacri Palitij Magistri. Ego Alexander de Angelis Societatis Iesu, et Sacræ Theologiæ Professor, legi quatuor libros Meteororum Io. Baptistæ Portæ Neapolitani, in quibus nihil inveni, quod sit contra fidem, aut bonos mores, sed dignos eos indico qui in lucem prodeant, si ita videbitur ijs, quorum interest. Data in nostro Collegio Romano die 22 Novembris, 1608.—"Ego Alexander de Angelis qui supra."

Towards the end of the sixteenth century, we find a greater freedom of physical thought beginning to be apparent; many eminent men now arose. Among them may be mentioned Telesio, Aconcio, Nizzoli, our countryman Gilbert, Giordano Bruno, and Galileo, great and original thinkers, worthy to be reverenced in all ages, for they broke down the barriers which had so long protected the Aristotelian philosophy, and by so doing prepared the world for the change about to be effected by the cardinal and sovereign intellect of Francis Bacon. Giordano Bruno suffered at the stake for the too open expression of his views; Galileo was compelled to resign his lectureship at Pisa, because he proved the fallacy of Aristotle's theory in regard to the velocity of falling bodies; at a later date he was imprisoned for daring to promulgate the Copernican theory of the earth's motion. These were the last great efforts of the hierarchy to curb and restrain the workings of the human mind, the last acts of oppression to be practised by a long dominant Church.

Although the Aristotelian philosophy had long been falling into disrepute, no system at all comparable to it had been propounded, and it was not till the publication of Bacon's "De Augmentis Scientiarum," that it received its death-blow. Mankind was now taught to interrogate Nature, not by reason alone, but by reason aided by experiment; not by the use of the syllogism, but by induction. From this period commences the epoch of modern science.

A few literary societies appeared in Italy in the fifteenth century, but their formation was not encouraged. In 1468 Paul II. arrested the members of a literary society on the charge of introducing foreign superstitions. They were ordered to be tortured and imprisoned for a year.

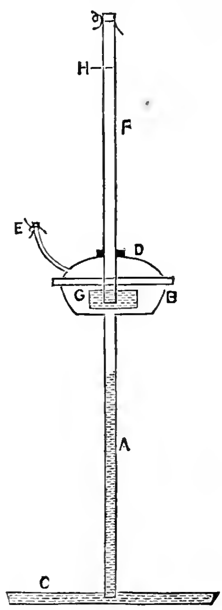
In the sixteenth century, societies became much more numerous; they existed, however, almost exclusively in Italy, and were generally devoted to the improvement of the Italian language, or to the study of the Platonic philosophy.

The first scientific society was established by Baptista Porta in the middle of the fifteenth century. It was called the "Academy of the Secrets of Nature," and consisted solely of men who had discovered something of importance in medicine or natural philosophy. From the name of the society it was believed that magic and illicit arts were practised by its members. Porta was summoned to appear at Rome, and commanded by Paul III. to discontinue the meetings of the society. While in Rome he was elected a member of the "Lyncean," a very celebrated academy, to which Galileo also belonged.

The first scientific society of importance was the Accademia del Cimento, established in Florence in 1657, by Duke Leopold of Tuscany. The object of this society was "to make experiments and relate them," and to ignore all theoretical matter. It proved worthy of its name "del Cimento," but, unfortunately for science, it endured only ten years, for Leopold was created a cardinal in 1667, and by leaving Florence withdrew his direct patronage from the society. During the ten years of its existence, however, a large number of ex-

periments were made by its members. A volume containing an account of them was published by the Secretary in 1667,* from which we extract the following relating to the subject under consideration.

In the early part of the work we find the description of a method of determining the comparative amounts of moisture in the air of different localities. The apparatus employed for the purpose was somewhat similar in form to the "ice calorimeter" of Lavoisier and Laplace. It consisted of a hollow metal cylinder lined inside with cork, open above, and terminated below by a cone. Ice was placed within it, and there was a lateral tube communicating with the interior for allowing the water produced by the liquefaction of the ice to flow away. The aqueous vapor in the atmosphere would obviously be condensed by the cold surface of the metal, and the water would trickle down the side of the cylinder, and finally drop from the apex of the cone; it was received in a graduated vessel. By noting the amounts of water collected in different localities in a given time, the comparative amounts of aqueous vapor in the air of those localities could be determined.



Under the title of "An experiment of Mr. Robervall's in favor of the air's pressure upon inferior bodies, tryed in our Academy," we have an account of a very ingenious experiment, performed by means of the following apparatus: A is a glass tube, forty-six inches long, terminated above by a cup-shaped enlargement B, and dipping below into a vessel of mercury C. B is furnished with a glass cover D, the edges of which are accurately ground so as to form an air-tight connexion with B. From D there projects a tube E. The cover D has an orifice in its upper part, through which passes air-tight a tube F, forty-six inches long, the lower end of which dips into a small vessel G, containing mercury, placed within B. Wet bladder is tied over the lower orifice of A. Mercury is now poured into the apparatus until it issues from E, which is then closed with wet bladder, and the pouring of the mercury continued until the tube F is full; bladder is then tied over its orifice. The bladder is now removed from the lower orifice of A, when the mercury immediately leaves the tube F and the vessel B, and remains suspended in A at a height of thirty inches above the mercury in B; the small vessel G will obviously remain full of mercury. On removing the bladder from E, the column of mercury in A immediately

* This work is in the form of a beautifully printed folio, with numerous full page plates of apparatus. It is entitled "Saggi di Naturali Ezperienze, fatte nell' Accademia del Cimento. E descritte del Segretario di essa Accademia. In Firenze, 1667." It was done into English in 1684 by Richard Waller, and printed by order of the Royal Society.

subsides, and mercury rises in F until it stands at A, a height of thirty inches above the surface of the mercury in the vessel G.

Many of the vacuum experiments described in the Proceedings of the Society were made in the Torricellian vacuum; but the air-pump was also used. Some of the experiments of this nature relate to the behaviour of birds and animals in rarefied air. Fishes were placed in a receiver, in a vessel of water; on exhausting, they swelled out considerably, turned over, and quickly died. When dissected the air-bladder was found to be empty. An eel lived for some time in vacuo, but was found to be dead at the end of an hour; the air-bladder, as in the case of the fish, was empty.

Pascal found that a bladder partially inflated at the level of the sea became wholly inflated on the summit of a mountain. Robervall made the same experiment with a carp's bladder, which burst when placed in the Torricellian vacuum. This suggested to some of the members of the Academy the idea that the expansion of air, " when at absolute liberty in any place," might be determined by annulling the atmospheric pressure by the weight of a column of mercury below the air, the expansion of which it is desired to determine. Accordingly, two similar tubes, open at one end, and terminated at the other by a bulb, were filled with mercury. One was inverted and opened under mercury in the usual way of performing Torricelli's experiment; into the other a small quantity of air was introduced before the tube was inverted. By calculation it was found that the air had expanded to 173 times its original bulk, but the experiments were not very concordant.

I may mention, in passing, that the experiment proving the incompressibility of water, by causing it to force its way through the pores of a metal, which is universally attributed to the Accademia del Cimento, was performed many years earlier by Bacon,* who used a sphere of lead for the purpose, while the academicians employed a sphere of gold.

In the next paper we shall consider the early labors of the Royal Society and of the Academie des Sciences relative to the subject under discussion.

(To be continued.)

The Economy of Pumping Engines Practically and Commercially Considered.

From the London Artizan, August, 1865.

One of the earliest applications of the dynamic power of steam was in raising water, as is shown in the writings of the oft-quoted Marquis of Worcester, whose method was subsequently improved by Captain Savery; but it was not until the invention of Newcomen's engine that anything like practical success was achieved; and even that, ingenious as it was, considering the age in which it was produced, presented an ungainly aspect, and yielded but little work for the fuel consumed.

* See "Novum Organum." Book 2. Aph. 45.

Different, indeed, is the present Cornish pumping engine, improved, as it has been, by the powerful intellects brought to bear upon the first crude form, by Stephenson, Watt, Wicksteed, and others, both of the past and present time.

Our object, however, at present is not to occupy space with matter merely historical, but to establish some criteria as to the most suitable forms in which pumping engines may be applied in the different localities and under the diverse circumstances which present themselves to the hydraulic engineer.

If the question resolved itself merely into the relation of the fuel consumed and duty done, it would at once be settled by reference to certain well established experiments, or, more correctly, results of working. Thus, two double-acting engines at Vauxhall, in 1843–44, which were constructed by Messrs. Fenton, Murray & Wood, consumed 11·5 lbs. of coals per horse power, whereas two Cornish engines at the East London Water-works, averaging seven years to 1850, yielded more economical results, consuming only 2·99 lbs. of coal per horse power per hour. In these cases the circumstances were so similar that decision in favor of engines of the Cornish class was arrived at, and on that principle the machinery at the Vauxhall Water-works was subsequently designed. On the other hand, it must be remembered that Cornish engines are costly and large in proportion to their power, their movements being comparatively slow and action single; hence, in cases where the power required is small, and space an object, it may sometimes be found that the advantages of the Cornish engine are outweighed by its disadvantages.

Direct-acting or bull engines are usually stated not to be nearly so economical in their working as the Cornish engines, but the cause of this may not at first sight appear clear. It is, however, by some supposed that it is due to the equalizing influence of the heavy beam upon the motion of the engine; if so, this can, of course, be obtained by attaching a vibrating wheel to the machine, but we are not inclined to attribute what inferiority may exist to this cause, but rather to a less perfect arrangement of the working gear.

The economy of the Cornish engine is, doubtless, due to two peculiarities; first, the high degree of expansion employed; and second, the mode of applying the dynamic force of the steam to propel the water. The advantages of applying steam expansively, so well known now to engineers generally, appear to have been early appreciated by the Cornish men, whether accidentally or by scientific research, as far as we are concerned, it matters not; but these are available to a greater extent at the opening of a mine than afterwards, as an engine of greater power than at first requisite, will usually be erected, and, of course, the steam can then be cut off very early in the stroke; but as the works extend, and more water flows to the pump well, more steam is needed, and, consequently, so high a degree of expansion as was commenced with is not maintained.

The experiments tried on the Cornish engine at the East London Water-works showed the following effects: When there was no ex-

pansion, the duty done being taken as 100; it was when the steam expanded through 0·397 of the stroke, 162·6, and when through 0·687 of the stroke, 224. While speaking of trials, it is desirable to refer to a source of error existing in some of the reports of duty in Cornwall, that is, the inefficiency of pump valves. In the case of the Holmbush engine, the water actually raised was 14·7 per cent. less than the calculated quantity adopted in reporting, and this loss appears to represent the quantity of water which ran back through the valves of the pump while they were closing; thus the duty represented by the steam power was 231, 486, 192 foot pounds per 112 pounds of coals, and the useful effect with Welsh coals only 122, 376, 128 foot pounds. This duty is high, but it must be mentioned that when the trial was made, the engine had not long been erected, and was doing but light work—the diameter of the cylinder being 50 inches, and stroke 9 feet 1 inch, while the horse power was but 26·5 horses. Thus the area of piston being 1963·5 square inches, the allowance per horse power would be 74 square inches, and the steam expanded through 0·83 of the entire stroke, or nearly five times its initial bulk, its pressure varying from 24·98 lbs. per square inch, down to 4 lbs. per square inch.

In comparison with the duty above mentioned of the Holmbush engine, we may take some of those reported in Cornwall for September, 1864. The following list comprises those out of thirty-four, which exceeded the average duty of 49,800,000 foot pounds per 112 lbs. of coal:

Boscawen, 70 in.,	52·2	millions.
Chiverton, Cookney's 60 in.,	57·0	"
Cargoll Mines, Michell's 72 in.,	58·6	"
Carn Brea, 76 in.,	50·0	"
Cook's Kitchen, 50 in.,	53·9	"
Crane, 70 in.,	64·5	"
Great Wheel Busy, Harvy's 85 in.,	63·2	"
Great Work, Leed's 60 in.,	60·3	"
North Wheal Crofty, Trevenson's 80 in.,	52·0	"
South Wheal Frances, Marriot's 75 in.,	55·9	"
West Caradon, Elliott's 50 in.,	70·8	"
West Wheal Seton, Harvy's 85 in.,	56·1	"
Wheal Ludcott, Willcock's 50 in.,	53·0	"
Wheal Margery, Wesley's 42 in.,	55·6	"
Wheal Seton, Tilly's 70 in.,	59·6	"
Wheal Tremayne, Michell's 60 in.,	53·7	"

To this list we will append the duties attained at various times by some other pumping engines:

East London W. W., 80 in. Cornish,	97·1	millions.
" " " 60 in. Boulton,	47·7	"
" " " 80 in. C., highest duty,	103·0	"
" " " 90 in. Wicksteed,	81·8	"
" " " 90 in. with Welsh coal,	109·0	"

It should here be noted that the highest duties of the Cornish and Wicksteed engines are calculated for Welsh coal, from its relative evaporative value to that used at the East London Water-works.

West's engine, 11 years' average,	83·5	millions.
Taylor's engine, 8 years' average,	93·1	"

In tendering for the erection of certain pumping engines at the

Grand Junction Water-works, in 1844, the contractor was bound to guarantee each engine (having a 40-inch cylinder) during the first twelve months to do a duty of 73·8 millions.

This shows the extent of economy attained at the East London Water-works at that date to be very considerable, as it is highly improbable that any contracter would render himself liable to conditions involving a doubtful issue.

It is usually supposed that small engines are not so economical as large, but there are now some near London doing a duty of about 80,000,000 of foot pounds per 112 lbs. of coal.

We will now proceed to consider the second advantage of the Cornish engine, namely, the mode of applying the dynamic force derived from the steam in the cylinder.

The steam acts in raising a weight and drawing water from the well into the pump barrel, this latter item being small in proportion to the former; then the pressure being equalized on both sides of the piston, the weight which had been lifted falls, forcing the water through the outlet valve from the pump barrel, and drawing up the steam piston ready for another stroke. From Mr. Wicksteed's experiments* on the 80-inch Cornish engine, we quote the following particulars, to show the distribution of the steam power, averaging during the stroke those quantities which vary: Preponderating weight, 55,401 lbs. or 11·037 lbs. per square inch of piston; water raised by engine, 4,125 lbs., or 0·821 lbs. per square inch; cold water pump, 186 lbs., or 0·037 lbs. per square inch; hot water pump, 6 lbs.; air pump, 591 lbs., or 0·117 lbs. per square inch; friction 1,009 lbs., or 0·200 lbs. per square inch; imperfect vacuum, 3,664 lbs., or 0·730 lbs. per square inch; total 64,982 lbs., or 12·94 lbs. per square inch steam pressure on the piston.

Now, the effect of the steam in raising the preponderating weight is evidently produced most conveniently, for if, at the commencement of the stroke termed the in-door or steam stroke, the engine runs a little fast, no shock occurs, but the extra momentum is quietly absorbed by a slight increase of speed upward of the weight being raised. Then when the out-door stroke begins, the preponderating weight by its own gravity quietly forces the water out of the pump to wherever it may be required, coming gradually to rest at the termination of the stroke. The superiority of this mode is at once evident when we consider what may be called the riotous movement of the water in a pump worked by an engine with a fly-wheel, the direction of the water's motion being in this case reversed without allowing the current time to come to rest, and producing, as it were, a series of blows, destructive alike to the machinery and its economy, and to any observer the effect of hydraulic shocks may be made evident by placing the hand upon a main leading from a pumping engine, as thereon the beat of the pump valves may be felt even a mile from the engine. This transmission of blows is, of course, to be traced to the comparative inelastic quality of water. Then, again, the gradual failing pressure of expanding steam is not favorable,

* See Wicksteed's "Experimental Enquiry."

if it be directly applied to the propulsion of water, which, being liquid, cannot so well carry the varying effect without loss of power.

With regard to rotary pumps, all we shall observe is this: A *perfect* rotary pump, worked by an uniform moment of pressure, would probably be an improvement on the Cornish pumping engine, if its motive power could be produced as cheaply; otherwise, except for purposes of trifling importance, we do not feel disposed to place much reliance upon them. One of the most important details of the pumping machinery rests in the valves, upon the construction of which the smooth working of the engine mainly depends. When the old clack valves were used, the vibration due to their closing was something enormous, in some cases shaking the buildings to such an extent that the engine could only be worked for a few hours at a time; but when Harvy and West's double beat valves were introduced, this difficulty and that arising from loss of water while the valves were closing were at once obviated; subsequently, valves closed by numerous balls, or small india rubber flaps were introduced, and also valves consisting of cylinders perforated on their peripheries, and surrounded by india rubber straps were applied, as also a variety of other contrivances, most of them ingenious and some useful. The double beat valves may occasionally be fouled, as once happened at the Ajax engine at the East London Water-works, when an eel came up the wind bore of the pump; but such cases are exceedingly rare. Recently, surface condensers have been applied to Cornish engines, both at the Scarborough and Kent Water-works, and certainly this description of steam machinery appears to afford them great facilities for working satisfactorily, as all the water passing from the main pump may, if it be desired, be allowed to flow through the condenser, thus insuring a good vacuum.

In entering upon the next branch of our subject—the question of finance—great caution is needed, as the means of obtaining correct information are very scarce, and, when found, give data rather perplexing to generalize, especially for comparison with those relating to double-acting engines. The figures, which will be quoted, are taken from actual practice, not mere estimates. In the first place, it will be necessary to come to some conclusion as to criteria of horse power of Cornish engines, as usually worked. For this purpose, various particulars have been gathered which tend to show that, taking a wide range of practice, there is, on the average, an allowance of about thirty square inches of piston surface per horse power; and this does not appear unreasonable, as it corresponds to fifteen square inches per horse power, in a double acting engine, the mean velocity of the piston on both strokes, and including stoppages at the end of each stroke, may be taken, for an engine working regularly, as being about one hundred feet per minute, but in different engines the speed varies very considerably. Taking the allowance of thirty square inches per horse power as granted, the mean cost of bright Cornish engines will be found to amount to about fifty-four pounds per horse power, exclusive of boilers. This appears very heavy, but it applies to engines of average dimensions, and includes the pump work and duplicates of the valves; and of this amount the main pump work costs about twenty-five per

cent., or about £14 10s. per horse power, leaving for the price of the engine proper about £39 10s., or nearly four times as much as an ordinary horizontal engine would cost.

It would be scarcely worth the while here to enter upon the question of current expenses, as these are exceedingly various. Thus it would require no more labor to work a one hundred horse engine than a fifty horse. Hence in the former case, as compared with the last, the cost of labor would appear unusually small. Two examples will suffice: Cost of labor per horse power per annum was, for two double engines at the Hull Water-works in 1845, £5·991, and for two Cornish engines at the East London Water-works, averaging seven years to 1850, £1·852 only. Cost of stores are more uniform, varying from £2·341 down to £0·784, showing an average of £1·483 per horse power per annum.

Some idea, may, however be formed as to the cost of raising water, from the following statistics, which give the cost per 1,000 barrels of 36 gallons each raised 100 feet, including the entire works, engines, buildings, &c., capital being taken at the interest of five per cent. per annum:

Total cost, average, of nine years, . .	18·114*d*
Total cost, average, of five years, . .	21·336*d*.

The two engines worked day and night during the first period; during the second one worked in the day only. After these engines were improved by the introduction of Harvy and West's valves, and by coating the boilers and steam pipes more effectually—

Total cost, average, of nine years; . .	20·452*d*
Total cost, average, of five years, , .	16·437*d*.

The second period being, of course, that during which the improvements were in use, the saving thus obtained was nearly twenty per cent. per annum.

On a Self-acting Apparatus for Steering Ships. By Dr. J. P. Joule, F.R.S.

From the London Artizan, March, 1865.

Some investigations in which I have been recently engaged, have led me to the construction of magnetic needles having considerably greater directive power than those in common use. It has occurred to me that it might be possible to apply the power, thus increased, to the purpose of the automatical steering of ships. My idea is to suspend a large compound system of needles or magnetic bars in the way first described by Professor Thomson, viz: by threads or fine wires attached above and below the system. By means of an electro-magnetic relay it would be possible to start a powerful machine in connexion with the tiller whenever the ship deviates from a prescribed course.

Suppose a system to be composed of a thousand 4-inch bar magnets, each $\frac{1}{4}$ of an inch in diameter, arranged in a vertical column, say 5 in

breadth and 200 hundred in height. According to a rough estimate I have made of the directive force of such a system, I find it to be equal at one inch from the axis of revolution to 300 grains, when at right angles to the magnetic meridian. This corresponds to 31 grains at 6° deflection, and 5 grains at 1°. Five grains would be amply sufficient to overcome any resistance to motion offered by a mercury commutator, and 30 grains would be more than sufficient with a properly constructed solid metallic commutator.

I would have a bent wire affixed to the lower end of the system of magnetic bars, one extremity of which should be immersed in a central cup of mercury, and the other should dip in one or the other of two concentric semicircular troughs of mercury exterior to the central cup.

I would place the central cup in connexion with one of the poles of a voltaic battery. The other pole must be in connexion with a branched conductor leading to two electro-magnets. The free wires of these electro-magnets should be put in connexion with the semicircular troughs.

By this arrangement it is obvious that accordingly as the wire carried by the magnetic system is immersed in the one or the other of the semicircular troughs, one or the other of the electro-magnets will be excited.

An armature should be placed between the two electro-magnets, so as to reciprocate between them whenever the wire passes from one semicircular trough to the other.

In so doing, I would have the armature, suitably connected by levers, &c., to operate on easily acting valves, (throttle valves, for instance,) placed in steam pipes proceeding from a steam boiler to opposite ends of a cylinder. A similar arrangement might be made for working the exit valves.

The piston of this cylinder should be connected with the tiller in such sort that whenever the ship turns to the right, the helm will be put to port, so as to bring her back to her course.

It is obvious that, if the dipping bent wire is in the direction of the magnet axis of the compound system of magnets, and the division between the semicircular troughs is in the direction of the ship's length, the ship will be kept directed to the magnetic north. By turning the commutator in the direction of the hands of a clock, the ship will at once change to a course the same number of degrees west of north.

The use of such an apparatus as I have described would, of course, be limited to very extraordinary circumstances. In general practice it will be impossible advantageously to displace the intellectually guided hand of the steersman, whose art consists in a great part in anticipating the motion of the ship, and in heavy seas in directing his ship so as to encounter them with safety.

In the discussion which followed,

Prof. Wm. Thomson said that the general idea contained in the paper was similar to one he had heard described by a friend some time ago, regarding a self-recording compass. But the plan of carrying

it out was very different. The plan upon which it acted was, that occasionally something should be moved up to meet the needle, whose position was thereby recorded. For instance, a circle carrying thirty-two stops should be moved up occasionally by clock-work until one or other of those stops would be touched by the needle, and a relay moved accordingly, so as to produce a record of the position of the needle at that instant. The plan described by Dr. Joule was essentially different; and the reasoning in the paper bore out the practicability of the plan. No doubt there might be circumstances where the practicability of the plan might prove useful, although, as Dr. Joule had said, there might not be any very extensive use for it.

Professor Rankine said that from Dr. Joule's description of this contrivance, it appeared to be practicable, and that it would work when executed. The shifting of the tiller by the action of steam applied to a piston was a practice already known. The new part of this invention was the self-acting method of operating upon the valve, which regulates the admission of the steam to the cylinder. Now, although Dr. Joule had said that it keeps the vessel in a particular course in calm weather, but would require the assistance of a helmsman in rough weather, yet he believed it would turn out to act just as a skilful steersman did. The steersman in crossing a wave allows the ship to fall off a little, and then brings her up again; and that was what he thought this contrivance would do—it would allow the bow of the ship to fall off a little at one time, and bring it up at another, and would always correct the deviation. He thought that in practice it would be found to do everything that a skilful helmsman does in crossing the swell of the Atlantic. The fact was, that he had a better opinion of its practicability than Dr. Joule himself seemed to have.

The President did not quite understand how these combined needles were to be worked. It would be most important if any means were devised whereby the course of a ship could be set and kept to by a self-acting steering apparatus. Steering by the aid of steam power had been in use in America, but it required a man continually to attend it. He would like to know whether the magnets were difficult to keep in order.

Mr. D. Rowan said, that assuming the magnets were quite competent to close the valve, he thought there would be great difficulty in getting the piston to do its part, for in admitting the steam the piston would be apt to go the whole range. He thought there would be difficulty in regulating the steam.

Prof. Rankine replied that, since steam could be regulated so that with the steam hammer a nutshell might be cracked without breaking the kernel, there could not be any very serious difficulty in applying it to steering.

Mr. T. Davison asked whether the combination of magnets would prevent the usual oscillation in compasses aboard ship.

Dr. Joule remarked that a great improvement might be made in the compasses of ships. In coming from Liverpool that morning by steamer he observed the mate "tapping" the compass to get it to work. Now,

he had no confidence in a compass that required "tapping." He thought there was no plan equal to that Professor Thomson had introduced, having the instrument fixed at the top and bottom to a filament. With regard to the combined magnets, it was simply using a pile of bars or magnets, so as to increase the power. The bars might be circular, or flat, or otherwise; and as to the number, suppose there were five to begin with, four inches long, and half an inch asunder, they could be piled up so as to give a directive power many times as great as that of one magnet. The oscillation was nearly the same as when only using one, although the power was increased. The magnets could be continued up to any height desired. The oscillation would be at the same speed as a light bar; but there would be power to set in motion a relay, which, communicating with the valves, would let off and on the steam.

Professor Thomson said that he felt much interested in the degree of the separation of the bars. In his endeavors to control the pendulum of St. George's church clock by an electric current from the Observatory, he adopted the plan of forming a magnet of a number of bars of watchmaker's rod steel, but he did not find the directive power increased in proportion to the number of the bars; for instance, he found that a magnet composed of 69 bars did not give more than about twelve times the power of a single bar. It would be supposed that 100 bars would have 100 times the directive force of a singlo bar, but he found that when placed close together, they demagnetized each other temporarily to a large degree, and recovered their previous magnetic strengths when separated. It thus appeared that the power depended on the distance they were placed apart, so that if they were placed on the principle adopted by Dr. Joule the power might be increased five or six fold. The advantage of separating the bars, even a small distance, was great; and if circumstances permitted, they could even be separated widely; then the power was still further increased.

Mr. J. G. Lawrie asked how it would do to separate them 2 inches or 4 inches?

Dr. Joule said that depended on the length of the bars. His bars were 4 inches long and separated half an inch.

The President asked how, with the method of suspension described, the magnets could be kept in a vertical plane when the ship rolled?

Dr. Joule said that he had no doubt that difficulty might be got over.

Mr. Lawrie said that if the suspending filaments were long it would be impossible to keep them quite straight. There would be a *sag* upon them.

Note by Dr. J. P. Joule, received after the paper had been read: I find on trial that a much smaller number of magnets than I have given is able to work a mercurial commutator. Fifteen 4-inch bars would be amply sufficient to overcome the adhesiveness of the mercury to the wires dipping into it when the deflection is one degree. A similar observation applies to the metallic commutator. Professor Thomson, however, has shown me a far more delicate mode than either of the above. In this plan a single bar magnet is suspended by a fine

platinum wire. To one arm of the magnet a platinum wire is attached vertically. Two horizontal parallel fixed wires are placed on either side of the suspended one. Whenever either of the fixed wires is, by the motion of the ship, brought into contact with the wire carried by the magnet, a current passes to it from the suspending wire. This current excites an electro-magnetic relay, by which another current is thrown upon an electro-magnet powerful enough to work the valves of the steam cylinder. Experiments conducted in the Physical Laboratory of the University are quite conclusive as to the practicability of this plan, and demonstrate the possibility of directing a ship by the agency of a needle much less powerful than that of an ordinary compass.

On Safe Safes. By Henry Dircks.

From the London Athenæum, February, 1865.

The successes of burglars in recent cases of robbery occurring in the city, despite the publicity of situation and the supposed vigilance of the police, has caused considerable alarm for the safety of property consigned to the supposed impregnable iron safes, as provided by approved manufacturers. It is true that as depositories of treasure and valuable records, modern iron safes are constructed with much skill and a large force of ingenuity, particularly in the matter of bolts and locks. They succeed, too, in resisting the influence of fire, but it has been proved at a dear cost that they are far from being thief proof.

If a plan could be proposed, untrammeled by a patent, that supplied the "one thing needful," who can doubt but it would be immediately adopted? At least, such is by no means an uncommon opinion, and therefore it may reasonably be hoped that the present suggestion will not be the less esteemed for public offices, the legal profession, bankers, jewellers, and others, to whom it is principally offered, and with whom it will now rest to require its adoption in the safes of their establishments.

Unfortunately, however, it is to be feared that, so far as the public is concerned, inventions given for nothing go for nothing. But some shrewd tradesman may make such modifications as may entitle him to letters patent, or at least a registration of his design based on this proposed method of infallible security.

The weak point in all our present safes, of whatever kind, is that they can be forced or broken open. No safe resists steel wedges, drills, chisels, crow-bars, and screw-jacks; and it is against these rough and ready usages that, no remedy having been yet attempted, one is now offered as simple as it certainly would prove effectual. The safemaker will boast, when a lost key obliges the picking of a lock, or the removal of a lid or door, that two at least of his best workmen had been occupied so many hours, which is invariably offered as irrefragable evidence of security. But the burglar, with few tools, little light, a confined space, and perhaps the while trembling for his own security, does

the business of opening in a very inconsiderable space of time. Let us now consider the mechanical means for frustrating the utmost skill and ingenuity of the most expert of this dangerous class of the community.

First, then, as to the principle. It consists in this: that the safe has within it a lever, properly suspended and secured, in communication with the inside of the door, which, whenever and however opened, rings an alarm.

And, second, a few words will suffice to show that, as to the modes of applying this principle, it admits of being infinitely varied. An obvious illustration is offered by such shop doors as have a catch at the top and a spring bell on the door frame; but more care would be required in the contrivance for the present purpose. One essential part would be the providing of a sliding bolt passing through the top, back, or any accessible part of the safe, to which to attach the inside and outside wires. It may consist of a solid plug of iron or steel, perhaps one inch in diameter and three or four inches long, screwed into the safe, and having a hole drilled through it of a quarter or half inch in diameter to admit a sliding bolt, which need not slide above one or two inches, and should be so contrived that it can never draw entirely in or out, so that in the event of fire the safe remains as securely plugged by the bolt as if it were a rivet, and perfectly inaccessible to heat; and it would require to have an eye or ring at each end for attaching the bell-wires. Having now obtained this sliding motion, we have only to make a bell wire fast to it on the inside of the safe, and to secure the other end of the wire to the lever, while the opposite end of the sliding bolt has a bell-wire fastened to it in communication with some remote chamber out of hearing in the vicinity of the safe, so that the alarm is only heard by the housekeeper or other attendant in charge. About the middle and near the top of the door on the inside, an aperture in the case or boss screwed thereon, would have to be arranged so as to receive the end of the lever, and slightly nip or lock it by means of a spring, but which, on opening the door, should both easily release itself and at the same time draw the lever sufficiently forward to operate on the sliding bolt, and thereby ring the housekeeper's or any other bell. This means of attachment is well understood, so that it requires no very particular detail, and it is quite clear that no large safe built in a wall, such as commonly used in public offices and most of our large private establishments, having this simple protection, could be effectually assailed without removing most of the brick or stonework. A further advantage is, that the catch is self-adjusting, so that *every* opening and shutting of the safe would be distinctly announced; and no external appearance would indicate the presence of this simple but formidable opponent to successful robbery.

It is one great advantage of this plan that the thief can have no means of ascertaining how to cut off the bell wires, and his very efforts to burst open the door give warning at a distance to call in assistance to prevent his escape from the hands of justice.

Inventors and the Crown.

From the London Mechanics' Magazine, February, 1865.

Until within the last day or two it was considered an axiom of English law, that "for every wrong there is a remedy." To the Admiralty, however, belongs the credit of having discovered, or led to the discovery of, a wrong for which their seems to be no remedy in the law as it now stands. It was really necessary to the credit of this department that their Lordships should discover the North Pole, or something. The case of "Feather *versus* the Queen," came as a windfall to "My Lords," when it was greatly needed, just as if it had been conjured up on purpose.

There were several important cases looming in the future, inventions—such as the Chalmers target—which have attracted a great deal of public attention, and which the Admiralty has, both in Parliament and by the press, been accused of pirating. To have opposed such cases by merely raising technical questions and legal quibbles, would have been ungracious as well as inconvenient; so Mr. Feather's invention, of which the public knew nothing, with which it had no sympathy, turns up just when wanted: the right thing for "My Lords," at the right time, and, so far as present appearances indicate, in the right place.

The case of "Feather *versus* the Queen," bids fair to become a *cause celebre*, not from anything extraordinary in the case itself, but from the fact that it has been *selected* by the Admiralty as a favorable medium to establish a claim, which, according to the Lord Chief Justice, "the legal advisers of the Crown had hitherto considered so monstrous that they would not set it up." Hence it is advisable to notice briefly, not the case itself, (the merits of which have not been gone into,) but the "monstrous" precedents which the Lords of the Admiralty, aided by the "ingenuity" of Sir Roundell Palmer are endeavoring to establish. The case was a petition of right against the Queen for an infringement by the Admiralty, in the construction of the "Enterprise," of a patent granted to the petitioner for an improvement in the construction of ships of iron, or partly of iron and partly of wood, so as to make them impervious to shot, and thus the better adapt them for purposes of naval warfare. The Attorney-General, on behalf of the Crown, not only denies the novelty and utility of the invention, but demurs to the petition of right, with the view of raising two important questions of law,—first, whether patents of improvements or inventions useful for the defence of the realm bind the Crown, or, if so, whether such patents are valid; and, secondly, assuming that they are so, whether a petition of right will lie against the Crown for a wrongful and illegal act of any of its servants, such as, it is said, the breach of a patent, if valid, would be. The law officers of the Crown, he said, had been led to raise these questions in consequence of the great increase in the number of patents for alleged inventions or improvements in the construction of weapons, vessels, or munitions of war, and of petitions of right for illegal infringements of them by pub-

lic departments, such as the Ordnance or Admiralty, and the great embarrassment and expensive litigation arising from unfounded claims thus brought forward against the Crown. He reverted to the case of "Clare *v.* the Queen," tried two years ago, and stated that the number of similar patents had so increased and threatened to give rise to such an amount of litigation, and to cause such serious obstruction to the public service, that it had been deemed right to take the judgment of a court of law upon the two great questions above stated,—whether such patents are valid as against the Crown, and whether, if so, the breach of them can be the subject of a petition of right. The Attorney-General then entered into an elaborate review of the authorities as to royal letters patent, and their effect as against the Crown, citing from "Coke's Reports," time of Elizabeth, consequently before the statute of James I., from "Blackstone's commentaries," &c., and he contended that this applied to the class of patents he was now dealing with.

The Attorney-General also strongly relied on the law which he cited from the case of Magdalen College, decided *temp.* James I., reported in 11, "Coke's Reports": "That even statutes if general, and not mentioning the Crown, do not bind the Crown, unless the scope of the statute shows that its very object requires that it should do so." Whence he argued that this must, *a multo fortiori*, be so in letters patent which emanated from the Crown itself; and that the law will never make an interpretation to advance a private and destroy a public benefit, but to advance the public benefit and prevent the private.

He further maintained that the Crown could not be excluded by its own patent from the use of an invention necessary for the defence of the realm. Upon these grounds, he said, it had been deemed necessary to raise the question whether such patents were valid as against the Crown, confining his arguments strictly to cases such as concerned the public interest and the defence of the realm, and declaring that there was no disposition to deal illiberally with inventors of real improvements, who (as in the instance of Sir William Armstrong) were rewarded, whether they had patented their inventions or not. But, assuming that he was wrong in this view, and that such patents were valid as against the Crown, then, he argued, as their infringement would be a wrongful and illegal act, it could not form the subject of a petition of right, which did not lie against the Crown for any illegal act of its servants.

This much was necessary to give an idea of the "monstrous" nature of the "rights" now claimed by the Admiralty for the first time, and which will surprise the public as much as they have surprised and amused the Court of Queen's Bench. The judges seemed fairly carried away by the novelty of the case and the boldness of the Attorney-General, to whom they put what appeared very much like leading questions; whilst the chatty, conversational familiarity of our law courts, which has such a charm for foreign legal gentlemen, was transformed into something more like badgering, when Mr. Bovill rose to speak for the petitioner. He urged "that it was the first duty of the Crown to

secure a useful invention by purchase, not by piracy, which was really taking the property of another without compensation." It would serve little purpose at present to follow up Mr. Bovill through his lengthy address, and the hundred and odd interruptions by the judges and the Attorney-General, as the following decision, announced on Monday last, will unquestionably cause the case to be carried to a Court of Appeal; for whether Mr. Feather be disposed to prosecute the matter further or not, the case must be contested in the interest of inventors and patentees generally:

The Lord Chief Justice, addressing the Attorney-General, said: "I take the earliest opportunity of informing you that, having had the advantage during the intervals that have occurred in the discussion of this case of considering the arguments that have been adduced and the authorities cited, the Court has been enabled to make up its mind on this matter, and we feel it is unnecessary for us to trouble you further. But, at the same time, considering the great importance of the question before the Court, and the great probability of the matter being taken to a Court of Appeal, we think it best to consider and prepare a more careful statement of the views we entertain than we have as yet had an opportunity of doing. Our minds are made up, and judgment will be delivered to-morrow, or in two or three days. I may, however, intimate that at present you may take it that judgment will be given for the Crown."

Should this case be carried to the House of Lords, as it must if need be, it will there be dealt with as a case in equity, rather than in a merely legal sense, when such arguments as failed to produce any impression in the Queen's Bench will have their due effect. Such, for instance, as that referring to the insertion of clauses in letters patent, providing for the compulsory sale of patent rights upon terms to be arranged with the Treasury, and that which empowers her Majesty to insert conditions and restrictions. The arguments of the Attorney-General, that such clauses apply only to articles and not to processes, and that they were inserted because it might sometimes be cheaper and more convenient to purchase from the patentee than to manufacture, though merely begging the question, seemed to weigh with the Lord Chief Justice and his colleagues. But it is not likely they would have the same weight with the House of Lords, which would have regard more to the spirit than the letter of the law, and those clauses clearly indicate that no such prerogative as that now claimed was contemplated by the legislature. The House of Lords, also, will not attach so much importance to the precedents of arbitrary reigns as the Court of Queen's Bench; mere lawyers dearly love a musty precedent. Even the *Times*, the avowed opponent of patentees, more than half agrees with Mr. Bovill when he protests against an appeal to the practice and theories of arbitrary reigns. "As to the old authorities," says Mr. Bovill, "it was easy to find precedents for anything among them, and the further one goes back the stronger the authorities become in favor of the Crown."

The alleged reasons for the extraordinary course now adopted by

the Admiralty are "the great increase in the number of patents and of petitions of right for infringements," to which is added the strange announcement "that it has always been the practice of the Admiralty to reward liberally meritorious inventions." This latter assertion will be news to most of our readers, whilst the fact that only one case (which occurred a couple of years back) is mentioned as proof of the *great increase* in the number of petitions, seems to cast a doubt on the sincerity with which these reasons are advanced. The *motive* power which has set all this expensive legal machinery in motion can doubtless be traced to the Controller's department, and found, in the words of a contemporary, to be nothing more than "a desire on the part of Mr. Reed to deck himself in the plumes of others, without any questions being asked."

These days of change and improvement have came as a thief in the night upon the Rip van Winkles of this "singular institution." The fact of steam propulsion and iron armor for ships of war coming within one century has shaken the tottering fabric to its very base, and the officials are now anxious to restore the halycon days when the construction of wooden ships at a thousand pounds a gun was the chief duty of the Admiralty. This peace and quiet are now sought for by legally barring the door against all intrusive inventors. But "My Lords" and their advisers appear to have overlooked two important points. First, that the law's delay is quite a different thing from peace and quiet; and, second, the shutting of the door against improvements by legal process, if successful, will open more widely the floodgates of public opinion. Last year, on a motion for an inquiry by the House of Commons into one of those cases, Lord Clarence Paget refused a committee, on the ground that the Queen's Bench was open to the petitioner, and that he had carried his case there and been defeated. But if the "monstrous" assumptions now put forth by Sir Roundell Palmer be sustained, if it be found that inventors (like the negroes of the South) have no right which the Admiralty is bound to respect, and that to take their property without payment is the law of the land, other objections will have to be discovered, or invented, to meet the demands for inquiry that will assuredly be made on the opening of Parliament.

Since the above was written Mr. Feather's attorneys have informed the public, through the columns of the *Times*, "that the Crown has *admitted* all issues of fact in favor of Mr. Feather, who has taken a verdict, which is on record, against the Crown, with £10,000 damages." Now, as the Admiralty come into Court with the *declaration* "that they are willing to reward liberally all useful inventions," and as they have *admitted* Mr. Feather's claim, so that "his right to remuneration is not resisted on the part of the Crown upon the merits of his claim." Mr. Feather and his attorneys will feel quite easy as to the final issue. The incentive to vigorous action, on their part, being entirely removed by the aforesaid *admission* and *declaration*, they cannot be expected to fitly represent those patentees who are really aimed at in the assumptions set up by the Attorney-General on behalf of the Crown.

A Comparison of some of the Meteorological Phenomena of AUGUST, 1865, *with those of* AUGUST, 1864, *and of the same month for* FIFTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 11¼′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

	August, 1865.	August, 1864.	August, for 15 years.
Thermometer—Highest—degree, .	91·00°	96·00°	97·00°
" " date, .	3d & 4th.	11th.	2,'56; 4,'59.
" Warmest day—mean,	84·50	87·50	88·50
" " " date,	4th.	11th.	10th, '63.
" Lowest—degree, .	58·00	61·00	47·00
" " date, .	23d.	31st.	26th, '56.
" Coldest day—mean,	64·17	68·83	59·00
" " " date, .	23d.	31st.	26th, '56.
" Mean daily oscillation,	12·13	11·71	15·51
" " " range, .	3·29	2·73	3·69
" Means at 7 A. M., .	72·10	75·26	71·04
" " 2 P. M., .	81·02	84·19	81·37
" " 9 P. M., .	74·56	78·43	74·07
" " for the month,	75·89	79·29	75·49
Barometer—Highest—inches, .	30·141 ins.	29·938 ins.	30·255 ins.
" " date, . .	1st.	19th.	20th, '55.
" Greatest mean daily press.	30·127	29·915	30·229
" " date, . .	1st.	20th.	20 & 31, '55.
" Lowest—inches, . .	29·540	29·437	29·356
" " date, . .	22d.	3d.	20th, '56.
" Least mean daily press.,	29·557	29·456	29·388
" " date, . .	22d.	3d.	20th, '56.
" Mean daily range, .	0·089	0·082	0·094
" Means at 7 A. M., .	29·847	29·726	29·866
" " 2 P. M., .	29·814	29·694	29·837
" " 9 P. M., .	29·847	29·726	29·857
" " for the month, .	29·836	29·715	29·853
Force of Vapor—Greatest—inches,	0·890 in.	0·895 in.	1·024 in.
" " " date, .	5th.	2d.	1st, '54.
" " Least—inches, .	·294	·307	·268
" " " date, .	24th.	31st.	often.
" " Means at 7 A. M., .	·575	·633	·587
" " " 2 P. M., .	·596	·630	·594
" " " 9 P. M., .	·596	·673	·614
" " " for the month,	·589	·645	·598
Relative Humidity—Greatest—per ct.,	85·0 per ct.	90·0 per ct.	100·0 per ct.
" " " date,	22d.	21st.	26th, '54.
" " Least—per ct.,	41·0	38·0	27·0
" " " date, .	24th.	31st.	1st, '60.
" " Means at 7 A. M.,	71·4	71·3	76·1
" " " 2 P. M.,	55·3	53·3	55·9
" " " 9 P. M.,	69·1	68·7	72·9
" " " for the month	65·3	64·4	68·3
Clouds—Number of clear days,* .	8	4	9·5
" " cloudy days, .	23	27	21·5
" Means of sky cov'd at 7 A. M.,	61·3 per ct.	70·6 per ct.	56·1 per ct.
" " " " 2 P. M.,	66·1	77·4	61·3
" " " " 9 P. M.,	2 ·5	58·4	41.9
" " " for the month	51·0	68·8	53·1
Rain—Amount	2·993 ins.	1·539 ins.	3·829 ins.
No. of days on which Rain fell,	6	9	9·7
Prevailing Winds—Times in 1000,	s.74°13′ w·270	s 42° 39′ w ·298	s 75° 27′ w ·115

* Sky one-third or less covered at the hours of observation.

A Comparison of some of the Meteorological Phenomena of the SUMMER *of* 1865, *with that of* 1864, *and of the same Season for* FOURTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 11¼′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	Summer, 1865.	Summer, 1864.	Summer, for 14 years.
Thermometer—Highest—degree, . .	97·00°	96·00°	100·5°
" date, . . .	7th July.	26 Je, 11 Aug	21st July, '54
Warmest day—mean,	87·33	89·67	91·30
" " date,	28th July.	26th June.	21st July, '54
Lowest—degree, . .	58·00	51·00	42·00
" date, . . .	23d Aug.	12th June.	5th June, '59
Coldest day—mean, .	64·17	59·33	55·00
" " date, .	23d Aug.	11th June.	6th June, '61
Mean daily oscillation,	12·50	14·95	15·88
" " range, .	4·08	4·08	4·14
Means at 7 A. M., . .	73·55	71·66	71·22
" 2 P. M., . .	82·58	81·97	81·29
" 9 P. M., . .	75·32	75·14	73·85
" for the Summer,	77·15	76·26	75·45
Barometer—Highest—inches, . . .	30·141 ins.	30·087 ins.	30·281 ins.
" date, ...	31 Jy, 1 Aug.	21st June.	14th June,'52
Greatest mean daily press.,	30·127	30·038	30·251
" date, ...	1st Aug.	18th July.	13th June,'52
Lowest—inches, . . .	29·537	29·296	29·182
" date, ...	17th July.	9th June.	11th June,'57
Least mean daily press., .	29·557	29·358	29·262
" date, . . .	22d Aug.	9th June.	11th June,'57
Mean daily range, . . .	0·086	0·108	0·096
Means at 7 A. M., . . .	29·822	29·774	29·838
" 2 P. M., . . .	29·796	29·739	29·808
" 9 P. M., . . .	29·820	29·771	29·826
" for the Summer, .	29·813	29·761	29·824
Force of Vapor—Greatest—inches, .	0·917 in.	0·895 in.	1·059 in.
" date, . .	25th July.	2d Aug.	30th June,'55
Least—inches, . .	·294	·221	·142
" date, . . .	24th Aug.	28th June.	14th June,'61
Means at 7 A. M., .	·605	·542	·570
" 2 P. M., .	·622	·547	·578
" 9 P. M., .	·626	·589	·599
" for the Summer,	·618	·559	·582
Relative Humidity—Greatest—per ct.,	90·0 per ct.	97·0 per ct.	100·0 per ct.
" date, .	9 Je, 25 Jy.	25th July.	26A'54, 6J'56
Least—per ct., .	37·0	24·0	22·0
" date, . .	9th July.	28th June.	16th June,'63
Means at 7 A. M.,	71·9	68·1	73·1
" 2 P. M.,	55·5	49·4	54·1
" 9 P. M.,	70·5	66·3	71·1
" for Summer,	65·9	61·3	66·1
Clouds—Number of clear days,* . .	26	22	25·5
" cloudy days, . .	66	70	66·5
Means of sky cov'd at 7 A. M.,	60·8 per ct.	60·7 per ct.	58·7 per ct.
" " " 2 P. M.,	64·6 "	63·6 "	61·0 "
" " " 9 P. M.,	36·4 "	46·7 "	42·8 "
" " for Summer,	53·9 "	57·0 "	54·2 "
Rain—Amount, ...	9·943 ins.	7·527 ins.	11·895 ins.
No. of days on which rain fell, . . .	26	24	32·3
Prevailing Winds—Times in 1000,	s73° 42′ w·213	s63°49′w·290	s71°10′w·166

* Sky one-third or less covered at the hours of observation.

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CIVIL ENGINEERING.

On the Wear and Tear of Steam Boilers. By FREDERICK ARTHUR PAGET, Esq., C.E.

(Continued from page 157.)

From the Journal of the Society of Arts, No. 649.

DISCUSSION.—Mr. LEWIS OLRICK said there were some points in the paper with which he did not agree. It was stated by Mr. Paget that one cause of injury to steam boilers was the percussive action of the steam when suddenly cut off by the slide valve, which caused a recoil upon the sides of the boiler. On this point he would remark that, in the great majority of boilers used in England, the slide valve did not suddenly cut off the steam; in most cases the slide valve was moved by an eccentric, and the cutting off was gradual, and not sudden as in the case of the American engines; and this remark, therefore, only applied to those engines where the expansion gear acted suddenly. Allusion had been made to the straining of the cylinder covers. He had seen such cases, and he had also observed the foundation plate give at each stroke of the engine; but he had no doubt if Mr. Paget had examined the plates in such cases, he would have found that this was not caused by the percussive action of the steam, but was owing to an insufficient amount of metal, and insufficient strength put into the proper place. He had noticed this in the case of an engine of twenty horse power, which had been in use for many years in the factory of Messrs. Maudslay, where there was an insufficiency of metal in the proper place. He had never seen it where the cylinder covers were strong enough for the work they were expected to do. Another point mentioned by Mr.

Paget was, that the steam room in the boiler should be proportionate to the size of the cylinder; he should have been glad if Mr. Paget had stated what he considered to be the proper proportions. Reference had been made to the caulking of boilers under pressure. This might be done when a boiler was tried by the hydraulic test, but the proper way was to take off the pressure, and then caulk and put on the pressure again. It was only the question of a minute to pump the pressure up again, and a few strokes more gave the additional pressure, beyond the former one indicated by the chalk mark. The next point he would allude to was with regard to the feed-water. It would appear that many engineers did not consider it wrong to insert the feed-water pipe near the fire-box. Quite recently he had seen that done in the case of a locomotive in which a Giffard's injector was employed; and he would call the attention of those who had not considered the subject to the explanations which Mr. Paget had given as to the injurious action of the feed-water on the boiler plates. The next point in the paper had reference to the superior heat conducting power of thin boiler plates as compared with thick. This was no doubt the case, but in speaking of the American plates, Mr. Paget had omitted to mention the superior quality of those plates, which made it possible to use them of a thickness which would not be ventured upon in England. Within the last few years the quality of the best plates in this country had almost come up to the American standard, but those generally used were not so good. Allusion had been made to the voltaic action that took place in steam boilers, and the evils that might follow from it. Some years ago a pamphlet was published by Mr. Zerah Colburn, in which the action of steam boiler explosions was explained, and the question of the galvanic action was based upon the high authority of Professor Faraday, to which he (Mr. Olrick) would willingly bow. He entirely agreed with the general remarks in the paper with respect to explosions. They involved the sacrifice of a great amount of life and property, and he thought it would be desirable for the government to take this matter in hand, and to introduce stringent rules to make people more careful with their boilers. The greatest amount of mischief was occasioned by employing men to attend boilers who knew nothing whatever of the properties of the steam engine. It was a question which could not be too much impressed upon people, that there should be proper periodical inspections of boilers, according to the system adopted by the Manchester Association. Mr. Paget had mentioned the hydraulic test. There was a great difference of opinion amongst engineers on that question, but no doubt, as Mr. Paget had pointed out, practical experience led to the conclusion that in all cases where this test was carefully applied, there was much fewer explosions than where it was neglected. The cases of locomotive engine explosions had occurred solely on lines where that test was not employed. On the subject of the wear and tear of steam boilers, he would remark that the great cause was defined by the single word "neglect," often on the part of the designer and manufacturer. When a boiler was made too small, there must be forced firing, and the consequence of that was early destruc-

tion of the boiler. A further deteriorating cause was defective circulation producing similar consequences. There was one point which it was almost unnecessary to mention, viz: that if boilers were not properly stayed, they would give way earlier than if proper attention was paid to the staying. But the great evil arose after the boilers came into the hands of the owners, from employing unskilled persons to work them. The amount saved in wages in this respect was an injudicious economy, and it was a question whether parties who confided boilers to such people ought not to be made responsible in a court of justice in the event of explosions taking place. Amongst the various evils to which steam boilers were exposed there was none worse than bad feed-water, which was a frequent cause of their destruction. A most grievous evil was scale in the boiler, which lowered the heating power, and thus it was most important that it should be frequently removed. Scaling arose from bad water, but as rain water was not generally to be procured, they had to be satisfied with well water, which was generally very hard, and which led to large deposits of sulphate of lime in the boiler. For the removal of the carbonate of lime from the feed-water, he believed Dr. Clark's process was very effective, though the means by which the result was accomplished would appear strange to those unacquainted with the subject. Lime was added in excess, which caused the precipitation of the salts of lime already in solution, and thus the water was purified.* There was also another plan, which had been successful in preventing scale, known as Martin's invention, which he had no doubt was also efficient. In that plan the feed-water was made to pass through a cylinder containing plates arranged diagonally and filled with superheated steam; the water deposited its scale upon these plates before entering the boiler. The consequence of this was a clean boiler instead of the accumulation of scale. The usual way of removing scale was sending boys with hammers into the boilers and knocking it off, which often caused great injury to the structure of the boiler, from carelessness in the operation. He was sure they must all feel indebted to Mr. Paget for his valuable and exhaustive paper.

Mr. Stenson remarked that mention was made in the paper of the circumstance of the stay bars in boilers being in a crystalline state, and only requiring a slight blow of a hammer to break them. He had heard papers read before this and other societies in which this question had been debated, but there was one point which required first to be settled, viz: the real condition of the iron previous to its being made into stays. Was it crystalline before it was so used? or had it become so by use? He had been connected with engineering the greater part of his life, and he must say he had never met with an instance in which it was satisfactorily proved that the iron had been converted from its fibrous condition before use. It was asserted that percussive action tended to produce a crystalline condition of the iron. This might be so, but he required further proof of it. He had cut up and examined a great many piston rods and connecting rods of locomotive

* *Journal of the Society of Arts*, vol. iv., page 424.

engines working at great velocity; he had found them to be in various states—some partly crystalline and some entirely so, while others had remained fibrous throughout; and he had found the same characteristics of inequality in the tires of railway wheels. The leakage of boilers had been referred to in the paper, and he held it to be a very important subject for investigation. He knew from experience with boilers in his own use, that a very small leakage would destroy the plate from the outside. The oxydation commenced at the spot, not where the water leaked, but where it evaporated and the plate was dry. The destruction of the plate from this cause was so rapid that he had known a $\frac{3}{8}$-inch plate cut through by a small leakage in a few months after the boiler was put up. He had no doubt this was caused by the chemical action upon the plate. With regard to scale, Mr. Olrick had mentioned a plan which he regarded as efficient in preventing the usual effects of the deposition of carbonate and other salts of lime in steam boilers. There could be no doubt of the destructive effects of those deposits upon the plates of the boiler, as also of the retardation thus caused to the heat. He should be glad to hear some further explanation of Mr. Martin's process, as he regarded scale as the greatest element of destruction with which they had to contend in the working of steam boilers.

Mr. Adams, whilst agreeing to a great extent with what had been stated in the paper, took exception to the remark that the method of welding plates reduced their strength. He had seen many successful experiments in welding, by Bertram's process, at Woolwich, and it was invariably found, under ordinary circumstances, that the weld was the strongest part of the plate, for it was a well known fact that a piece of iron forged after it came from the rollers was stronger than when it left the rollers. Mr. Paget had quoted from some German authorities respecting the temperature at which water was decomposed, but he would state a practical fact within his own experience. On one occasion the steam was allowed to stand stagnant for ten days, and on the tenth day the metal of the superheater ran away into the fire, but no decomposition of the water had taken place. With regard to the hydraulic testing of boilers, engineers were not agreed as to whether the testing should be made at a high temperature or not. They knew, in testing a boiler cold, they had the friction of the rivets; but in hot testing the expansion of the metal by heat caused a great difference. The rivets expanded to a greater extent than the plate itself, because the expansion of the rivets was longitudinal and along the fibre, whereas the expansion of the plate was across the fibre and not so great, and the power which the friction of the rivets gave to the strength of the plate would be less when cold; but to oppose that there was the greater strength of the plate due to the low temperature. Mr. Adams then, by means of a diagram, described in detail Martin's process for preventing incrustation in boilers.

Mr. G. F. Wilson, F.R.S., on the subject mentioned in the paper as to water or steam in contact with iron being decomposed, would give an instance in his own experience where such was not the case at a very high temperature. It had come under his observation that steam

passing day by day through iron pipes at a red heat was not decomposed, or there was no evidence of its decomposition. The theory was that hydrogen ought to have been formed, and an explosive mixture should have been generated, but practically such explosive compound was not formed.

Mr. Olrick wished to add, with reference to the hydraulic testing of boilers, that he had in many instances used hot water for the test up to 200 degrees, as by that means the boiler was brought into a very similar state to what it would be in when at full work.

The Chairman said it now became his duty to move that the thanks of the meeting be given to Mr. Paget for the paper with which he had favored them. It was very comprehensive in its scope, and he thought contained many valuable suggestions. No doubt public safety was of the first importance in matters of this kind, and the mode in which that could be best obtained seemed to be practically indicated by the inspections undertaken by the Manchester Society. Other means, no doubt, might be taken for ensuring the safety of the public; but there was no plan so effective as when the public took care of itself, as was the case at Manchester. With regard to the economy of wear and tear, it was a question for engineers, and one upon which he could not venture to give an opinion; but, undoubtedly, it was an important question for those who employed steam boilers in their manufactories in which a large amount of capital was invested. They must all feel indebted to Mr. Paget for his careful investigation of the subject, and the able manner in which he had treated it in his paper.

The vote of thanks having been passed,

Mr. Paget, in acknowledging the compliment, said that a perusal of his paper would show that he had very carefully guarded himself from stating that any impulsive action on the sides of the boiler could be brought to bear by means of the gradual action of the side-valve. In speaking of the effect of galvanism on steam boilers, he, of course, only meant the chemical action on the plates producing wear and tear, and therefore to the primary ruptures leading to explosions. With respect to incrustations, he thought that the effects they produced were simply those which ensued when a plate got red hot. In speaking of the charcoal plates used in America, he was necessarily aware of their superiority to iron made with pit-coal. Testing boilers by means of hot w ter instead of cold, was often, as he said, very advantageous, and, indeed, necessary. With regard to the crystallization of iron, and with respect to Mr. Stenson's remarks, he thought that this state was simply due to strains in excess of the elastic limit, abstracting elasticity and ductility, and therefore inducing brittleness. The crystallized appearance of a surface of fracture was simply due to the mode of fracture. His observations with regard to Bertram's joints were founded on the results of experiments conducted at Woolwich for the Admiralty. With respect to boiler insurance companies, their action undoubtedly offered the best means of safety and economy; at the same time, their future spread needed some extraneous stimulus, more especially in sparsely populated districts, like the agricultural and some of the mining counties.

Professor Zeuner's Table of the Properties of Saturated Steam.

From the London Artizan, June and December, 1864.

The table we publish in our present number is a reproduction of that computed by Herr G. Zeuner, Professor of Applied Mechanics at the Federal Polytechnic Institute, of Zurich. We have added columns 3, 5, 7, 15, and 17, in order to render the results more intelligible to our readers. The table is based on the mechanical theory of heat. Prof. Zeuner states that he calculated the values given in the table by means of Thomas' calculating machine which proved very useful for this purpose.

The first column contains the pressure of steam in atmospheres, advancing by tenths of an atmosphere from one to seven, and by fourths from 7 to 14 atmospheres. In the second and third columns the same pressures are given in millimetres and inches of mercury, as denoted by the barometer; while in the fourth and fifth columns, the same pressures are given respectively in kilograms and pounds per square meter and square inch. The sixth and seventh columns contain the centigradial and Fahrenheit degrees of heat for the various pressures of saturated steam, as deduced by interpolation from Regnault's data. Thus, the temperature of saturated steam at a pressure of five atmospheres is 151·22° C = 306·00 F.

To render columns 8, 9, and 10 intelligible, the following deductions will be required: Supposing a certain space, for example, a cylinder of a section F to contain 1 kilogram of water at 0° (C), and, by heating it, saturated steam of a pressure of p (kilos per square metre) and a given temperature to be intended to be produced. The cylinder piston rests on the surface of the water, and at a distance s_1 from the bottom; the volume of water contained in the cylinder will be, therefore,

$$\text{F}\, s_1 = w.$$

The piston is also supposed, at the beginning of the trial, to be loaded by a weight p per unit of area, and the pressure on the piston to be equal to that of the steam to be generated. In heating the water, its temperature will at first rise from 0° to t° (C), before steam is generated; then, at a temperature t, the expansive force of the steam will be sufficient to overcome the pressure p, and thus to move the piston.*

Let q be the quantity of heat necessary to raise the temperature of the water from 0° to t°. This quantity, according to Regnault's formula, will be

$$q = t + \cdot 00002\, t^2 + \cdot 0000003\, t^3, \quad . \quad . \quad (1.)$$

If the heating process continues, steam will be generated that will reach the pressure p, and the piston will be pushed forward, until the whole of the water has been transformed into steam ; supposing, at this moment, the distance of the piston from the bottom of the cylinder to

* In all these calculations the kilogram, the metre, and the degrees of the centigradial thermometer are adopted as units. The columns 3, 5, 7, 15, and 17 were inserted in our table merely for the convenience of those not acquainted with the decimal (metrical) weights, measures, &c.

be $= s_2$, the volume of the unit of weight of steam generated at a pressure p will be

$$F s_2 = v.$$

During the evaporation, the pressure and temperature remain constant, the heat r that must be supplied during the operation is called *latent heat*, or, according to Clasius, *heat of evaporation*. The total quantity of heat that must be supplied to water at 0°, in order to obtain, under a constant pressure, the unit of weight of steam of a pressure p, is

$$Q = q + r \quad . \quad . \quad . \quad . \quad (2),$$

for which value of Q (generally called the *aggregate heat of steam*) M. Regnault gives the formula

$$Q = 606{\cdot}5 + {\cdot}305\,t, \quad . \quad . \quad . \quad (2a.)$$

Now, the steam has, during its generation, performed a certain amount of work, having acted with a pressure $F\,p$ on the piston, which has traveled through a space $s_2 - s_1$; the work done will be, therefore,

$$F\,p\,(s_2 - s_1);$$

or else, as we called

$$F\,s_2 = v \text{ and } F\,s_1 = w,$$

it will be

$$p\,(v - w).$$

The value $v - w$ represents the difference between the unit of weight (1 kilo) of steam at a pressure p, and the corresponding unit of weight of water, which latter may be considered constant at the various temperatures and $= 1$ cubic decimetre. To simplify the calculation, we shall call

$$v - w = u \quad . \quad . \quad . \quad (3),$$

so that the labor performed by the unit of steam during its formation will be $= p\,u$.

Now, according to the mechanical theory of heat, every production of work requires the transformation of a certain quantity of heat, and it has been ascertained by experiments that one unit of heat or a *calorie* can be produced by a quantity of work $=$ to 424 kilogrammetres; or reciprocately $\frac{1}{424} = A$ will be the quantity of heat corresponding to one unit of work, or one kilogrammetre. A is the calorific equivalent of one unit of work. In multiplying by A the quantity of work $p\,u$ required for generating steam under a constant pressure p, the coefficient

$$A\,p\,u$$

will represent the quantity of heat that is absorbed during this formation. From the quantity of heat Q required to transform at a constant pressure p one unit of weight of water of 0° into steam of a pressure p, will therefore be abstracted the quantity of heat $A\,p\,u$ during the process of generation of steam, *i.e.*, another quantity of heat J will be obtained through the equation

$$J = Q - p\,u, \quad . \quad . \quad . \quad . \quad (4.)$$

This is called *the heat contained in the steam*, or *the heat of steam.* J also indicates how many calories (units of heat) will be found in one unit of weight of saturated steam of a pressure p, in addition to those contained in one unit of weight of water at a temperature 0°.

The latent heat or *heat of evaporation* r, on the contrary, represents, according to our notations, the quantity of heat that must be supplied to the water that has already been brought to the temperature of the steam to be generated, in order to convert it into steam, supposing, however, the generation of steam to take place under a constant pressure. In deducting, therefore, the quantity $A\,p\,u$ of heat converted into work from the value r, the difference ρ will denote by what amount of heat the unit of weight of steam of a temperature t will exceed the unit of weight of water of the same temperature.

The coefficient

$$\rho = r - A\,p\,u \quad . \quad . \quad . \quad . \quad (5)$$

is called the *internal latent heat.*

The two quantities J and ρ are very important coefficients. They are both entirely independent of the way in which the steam is generated; whereas, in introducing in calculations the total heat Q, and the heat of evaporation r, it must be borne in mind that with them the generation of the steam is supposed to take place under a constant pressure.

The quantity of heat converted into labor during the process of generation of steam under a constant pressure may be noted with very great precision by the empirical formula

$$A\,p\,u = B \log \frac{T}{n}, \quad . \quad . \quad . \quad . \quad . \quad (6,)$$

in which B and n are two constants, for which in calculation 30,456 for B, and 100 for r have to be substituted. T is what is called the *absolute temperature, i.e.*,

$$T = 273 + t.$$

The column (8) has been calculated by means of formula (6).

The values of Q and r, in formulæ (4) and (5) being known from Regnault's experiments, the coefficients J and ρ may be deduced therefrom. In availing himself of these experiments, Prof. Zeuner found for the heat of evaporation, the formula

$$J = 573{\cdot}34 + {\cdot}2342\,t, \quad . \quad . \quad . \quad (7,)$$

for which he calculated the values contained in column (9).

He found, moreover, for the temperatures that are met with in steam engines, that the internal latent heat is represented by the formula

$$\rho = 575{\cdot}03 - {\cdot}7882\,t, \quad . \quad . \quad . \quad . \quad (8,)$$

from which the tenth column has been calculated.

Example.—Supposing the steam to act at a pressure of 5 atmospheres, the heat converted into labor is

$$A\,p\,u = 44{\cdot}083 \text{ calories},$$

for a quantity of labor corresponding to

$$44{\cdot}083 \times 424 = 18{,}691{\cdot}19 \text{ kilogrammetres},$$

the heat of steam being

$$J = 608{\cdot}99 \text{ calories},$$

and the internal latent heat

$$\rho = 455{\cdot}05.$$

From equation (4) is found, as the total heat of this steam,

$$Q = J + A\,p\,u = 653{\cdot}07,^*$$

and the heat of evaporation

$$r = \rho + A\,p\,u = 499{\cdot}13.^\dagger$$

The equation

$$J - \rho = q, \quad . \quad . \quad . \quad . \quad . \quad (9,)$$

which is obtained by deducting formula (5) from (6), will be found to agree with equation (2). From equations (7) and (8) is deduced, for the heat that can bring water from o° to t°,

$$q = -1{\cdot}69 + 1{\cdot}0224\,t, \quad . \quad . \quad . \quad (10,)$$

which is a convenient coefficient for the temperatures steam engines generally work at.

It may be concluded therefrom that the specific heat of water at average temperatures will be

$$c = 1{\cdot}0224, \quad . \quad . \quad . \quad . \quad . \quad (11.)$$

The foregoing explanations are sufficient to render the next columns of the table intelligible. Column 11 contains the values of u, which are obtained by dividing the coefficients $A\,p\,u$ of column 8 by $A\,p$. Column 12 contains the values of the coefficient $\frac{p}{u}$, deducted from columns 10 and 11. These latter coefficients will prove to be of very great importance in practice.

The value of equation (3) differs very little from v, the specific volume of water u being so small, as compared to w, that, in most cases, it may be neglected with safety. ρ denotes the internal latent heat of the unit of weight, and consequently, $\frac{p}{u}$ may be considered as *the internal latent heat of the unit of volume* (*i.e.*, 1 cubic metre) of steam.

The column 13 shows that the differences in the values of $\frac{p}{u}$ decrease very slowly with the pressure; this internal latent heat of the unit of weight is therefore proportioned to the tension of steam.

Finally, we may deduct from formula (3) the specific volumes of the steam, or the volume of 1 kilogramme of steam at different pressures, and

$$v = u + w \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

for the specific weight of steam we have seen that we may take $w = {\cdot}001$; in this manner the value of v may be obtained. These values

* Mr. Regnault's formula (2 bis.) gives 652·93.

† According to Regnault's formula $r = 499{\cdot}20$.

are contained in column 14 in cubic metres for kilogrammes, and in column 15 in cubic feet for pounds avoirdupois. The density γ, or weight of 1 cubic metre of steam at various temperatures, may be reciprocally obtained by the formula

$$\gamma = \frac{1}{v}, \quad . \quad . \quad . \quad . \quad . \quad (13.)$$

These values are contained in a like manner in columns 16 and 17, respectively for French and English measures and weight.*

We have given Herr Zeuner's table, with the deductions from which the results contained therein were arrived at. We now give, by way of example, the problem worked out by Professor Zeuner himself, in order to illustrate the application of the table.

The question to be solved is the following: *In what manner will the pressure of steam increase in a boiler which is continued to be heated after the egress of steam has been stopped, and the valve shut off from a certain moment.*

Supposing the weight of water and steam combined in the boiler to be M kilos., m kilos. of which being steam, at the moment the valve is shut off, $t =$ the temperature, p the pressure, and all other letters to denote the same as before, (see page 222,) the volume of water contained within the boiler will then be $= (M - m)\, w$, the volume of steam $= m\, v$; therefore the volume of the water and steam combined

$$V = (M - m)\, w + m\, v = M\, w + m\, (v - w);$$

or, by equation (3),

$$V = M\, w + m\, u.$$

Supposing the quantity of steam in the boiler to increase by the heating process, and m to assume the value m_1, t the value of t_1, and p the value of p_1, after the lapse of τ minutes; the value of u will become u_1, as there is no change in the volume, and we shall have

$$V = M\, w + m_1\, u_1$$

$$m_1\, u_1 = m\, u.$$

The quantity of steam, m, can therefore easily be calculated for every temperature t_1.

The quantity of heat that was contained in the water at the beginning was $= (M - m)\, q$, that contained in the steam was $= m\, J$; therefore the quantity of heat contained in the volume of water and steam combined will be

$$(M - m)\, q + m\, J = M\, q + m\, (J - q)$$

$$J - q = \rho \text{ (by equation (9))}$$

$$\therefore M q + m\, (J - q) = M\, q + m\, \rho.$$

For a temperature, t_1, we shall have

$$M\, q_1 + m_1\, \rho_1,$$

and consequently, the quantity of heat to be supplied, in order to raise

* 1 kilogramme = 2·205 lbs. avoirdupois; 1 metre = 100 centimetres = 3·2809 ft.; 1 square metre = 10,000 square centimetres = 10·76 square ft.; 1 cubic metre = 35·32 cubic feet.

TABLE *of the Properties of Saturated Steam.*

PRESSURE IN					TEMPERATURE.								VOLUME.		DENSITY.	
Atmospheres.	Millimetres of Mercury.	Inches of Mercury.	Kilogrammes per square metre. p	Lbs. avoirdupois per square inch.	Centigradial. t	Fahrenheit.	Quantity of steam converted into work during the production of steam. $A\,p\,u$	Heat of steam. J	Latent internal heat. ρ	Values of u.	Values of $\frac{\rho}{u}$.	Differences.	Volume of one kilogramme of steam in cubic metres. v	Corresponding volume of 1 lb. avoirdupois in cubic feet.	Weight of 1 cubic metre in kilogrammes. γ	Corresponding weight of 1 cubic foot in lbs.
0·1	76	3	1033·4	1·470	46·21	115·18	35·349	584·16	538·61	14·5034	37 14	32·95	14·5044	184·563	0·069	·0054
0·2	152	6	2066·8	2·939	60·45	140·81	36·679	587·50	527·38	7·5246	70·09	31·37	7·5256	95·760	0 133	·0105
0.3	228	9	3100·2	4·409	69·49	157·02	37·493	589 61	520·26	5·1278	101·46	30·34	5·1288	65·262	0·195	·0153
0·4	304	12	4133·6	5·879	76·25	169·25	38·089	591·20	514·93	3·9069	131·80	29·57	3·9079	49·726	0·256	·0201
0·5	380	15	5167·0	7·349	81·71	179·26	38·562	592·48	510·63	3·1644	161·37	28 96	3 1654	40·262	0·316	·0248
0·6	456	18	6200·4	8·818	86·32	187·38	38·954	593·56	506·99	2·6638	190·33	28·44	2·6648	33·909	0·375	·0295
0·7	532	21	7233·8	10·288	90·32	196·36	39·292	594·49	503·84	2·3030	218·77	28·00	2·3040	29·318	0·434	·0341
0·8	608	24	8267·2	11·758	93·88	200·98	39·589	595·33	501·03	2 0304	246·77	27·61	2·0314	25·849	0·492	·0387
0·9	684	27	9500·6	13·227	97·08	206 74	39·853	596·08	498·51	1·8168	274·38	27·27	1·8178	23·131	0·550	·0432
1·0	760	30	10334 0	14·697	100·00	212 00	40·092	596·76	496·21	1·6450	301 05	26·97	1·6460	20·950	0·617	·0477
1·1	836	33	11367·4	16·167	102·68	216·82	40·310	597·39	494·10	1·5036	328 62	26·67	1·5046	19·145	0·665	·0523
1·2	912	36	12400 8	17·636	105·17	221·31	40·512	597·97	492·13	1·3851	355·29	26·41	1·3861	17 638	0·722	·0567
1·3	988	39	13434·2	19·106	107·50	225·35	40·699	598·52	490·30	1·2845	381·70	26·18	1·2855	16·358	0·778	·0611
1·4	1064	42	14467·6	20·576	109·68	229·42	40·873	599·03	488·58	1·1978	407·88	25 94	1·1988	15·254	0·834	·0655
1·5	1140	45	15501·0	22·046	111·74	233·13	41·036	599·51	486·96	1·1225	433·82	25·74	1·1235	14·296	0·890	·0699
1·6	1216	48	16534·4	23·515	113 69	236·72	41·190	599·97	485·24	1·0563	459·56	25·55	1·0573	13·454	0·946	·0743
1·7	1292	51	17567·8	24·985	115·54	239·97	41·336	600·40	483·96	0·9976	485·11	25·36	0·9986	12·707	1·001	·0787
1·8	1368	54	18601·2	26·455	117·30	243·14	41·473	600·81	482·57	0 9153	510·47	25·17	0·9463	12·041	1·057	·0831
1·9	1444	57	19633·6	27·924	118·99	246·18	41·605	601·21	481·24	0·8984	535·64	25·03	0·8994	11·444	1·112	·0874
2 0	1520	60	20668·0	29·394	120·60	249·08	41·730	601·58	479·97	0 8561	560·67		0·8571	10·906	1·167	·0917
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**

(TABLE CONTINUED.)

Pressure in					Temperature.		Quantity of steam converted into work during the production of steam.	Heat of steam.	Latent internal heat.	Values of u.	Values of $\frac{\rho}{u}$.	Differences.	Volume.		Density.	
Atmospheres.	Millimetres of Mercury.	Inches of Mercury.	Kilogrammes per square metre. p	Lbs. avoirdupois per square inch.	Centigradial. t	Fahrenheit.	$A\,p\,u$	J	ρ				Volume of one kilogramme of steam in cubic metres. v	Corresponding volume of 1 lb. avoirdupois in cubic feet.	Weight of 1 cubic metre in kilogrammes. γ	Corresponding weight of 1 cubic foot in lbs.
2·1	1596	63	21701·4	30·864	122·15	251·87	41·849	601·95	478·75	0·8176	585·52	24·85	0·8186	10·416	1·222	·0960
2·2	1672	66	22734·8	32·333	123·64	254·55	41·964	602·30	477·58	0·7826	610·23	24·71	0·7836	9·971	1·276	·1003
2·3	1748	69	23768·2	33·803	125·07	257·13	42·073	602·63	476·45	0·7505	634·80	24·57	0·7515	9·563	1·331	·1046
2·4	1824	72	24801·6	35·273	126·46	259·63	42·180	602·96	475·35	0·7211	659·21	24·41	0·7221	9·188	1·385	·1088
2·5	1900	75	25835·0	36·743	127·80	262·04	42·282	603·27	474·30	0·6939	683·50	24·29	0·6949	8·842	1·439	·1131
2·6	1976	78	26868·4	38·212	129·10	264·38	42·380	603·57	473·27	0·6688	707·66	24·16	0·6698	8·523	1·493	·1173
2·7	2052	81	27901·8	39·682	130·35	266·63	42·475	603·87	472·29	0·6454	731·71	24·05	0·6464	8·225	1·547	·1216
2·8	2128	84	28935·2	41·151	131·57	268·83	42·567	604·15	471·33	0·6237	755·63	23·92	0·6247	7·949	1·601	·1258
2·9	2204	87	29968·6	42·620	132·76	270·97	42·656	604·43	470·39	0·6035	779·42	23·79	0·6045	7·692	1·654	·1300
3·0	2280	90	31002·0	44·091	133·91	273·04	42·742	604·70	469·48	0·5846	803·12	23·70	0·5856	7·452	1·708	·1342
3·1	2356	93	32035·4	45·561	135·03	275·05	42·826	604·96	468·60	0·5668	826·72	23·60	0·5678	7·225	1·761	·1384
3·2	2432	96	33068·8	47·130	136·12	277·02	42·907	605·22	467·74	0·5501	850·20	23·48	0·5511	7·012	1·814	·1426
3·3	2508	99	34102·2	48·500	137·19	278·94	42·987	605·47	466·90	0·5345	873·57	23·37	0·5355	6·814	1·867	·1467
3·4	2584	102	35135·6	49·970	138·23	280·81	43·064	605·71	466·08	0·5197	896·86	23·29	0·5207	6·626	1·920	·1509
3·5	2660	105	36169·0	51·439	139·24	282·63	43·139	605·95	465.27	0·5057	920·05	23·19	0·5067	6·448	1·973	·1551
3·6	2736	108	37202·4	52·909	140·23	284·41	43·212	606·18	464·50	0·4925	943·16	23·11	0·4935	6·280	2·026	·1592
3·7	2812	111	38235·8	54·379	141·21	286·18	43·284	606·41	463·73	0·4800	966·14	22·98	0·4810	6·121	2·079	·1634
3·8	2888	114	39269·2	55·849	142·15	287·87	43·353	606·63	462·99	0·4681	989·09	22·95	0·4691	5·969	2·132	·1675
3·9	2964	117	40302·6	57·318	143·08	289·54	43·421	606·85	462·25	0·4568	1011·92	22·83	0·4578	5·833	2·184	·1716
4·0	3040	120	41336·0	58·788	144·00	291·20	43·488	607·06	461·53	0·4461	1034·63	22·71	0·4471	5·689	2·237	·1758
4·1	3116	123	42369·4	60·258	144·89	292·80	43·553	607·27	460·83	0·4358	1057·31	22·68	0·4368	5·558	2·289	·1799

4·2	3192	126	43402·8	61·727	145 76	294·37	43·617	607·48	460·14	0·4261	1079·91	22·60	0·4271	5·435	2·341	·1840
4·3	3268	129	44436 2	63·197	146·61	295·90	43·678	607·68	459·47	0·4168	1102·45	22·54	0·4178	5·316	2·393	·1881
4·4	3344	132	45469·6	64·667	147·46	297·43	43·740	607·87	458·80	0·4079	1124·87	22·42	0·4089	5·203	2·446	·1922
4·5	3420	135	46503·0	66·137	148·29	298·92	43·800	608·07	458·15	0·3993	1147·21	22·34	0·4003	5·094	2·498	·1963
4·6	3496	138	47536·4	67·606	149·10	300·38	43·859	608·26	457·51	0·3912	1169·51	22·30	0·3922	4·991	2·550	·2004
4·7	3572	141	48569·8	69 076	149·90	301 82	43·916	608 45	456·88	0·3834	1191·71	22·20	0·3844	4·891	2·602	·2045
4·8	3648	144	49603·2	70·546	150·69	303 32	43·973	608·63	456·26	0·3759	1213·85	22·14	0·3769	4·796	2·653	·2085
4·9	3724	147	50636·6	72·015	151·46	304·63	44·028	608 81	455·65	0·3687	1235·93	22·01	0·3697	4·704	2·705	·2126
5·0	3800	150	51670·0	73·485	152.22	306·00	44·083	608·99	455·05	0·3617	1257·94	21·93	0·3627	4·615	2·757	·2167
5·1	3876	153	52703·4	74 955	152·97	307·35	44 137	609·16	454·46	0·3551	1279·87	21·91	0 3561	4·531	2·807	·2206
5·2	3952	156	53736·8	76·424	153·70	308·66	44·189	609·34	453·88	0·3487	1301·78	21·79	0·3497	4·450	2·859	·2247
5·3	4028	159	54770·2	77·894	154 43	309·97	44·241	609·51	453·31	0·3425	1323·57	21·77	0·3435	4·371	2·911	·2288
5·4	4104	162	55803·6	79·364	155 14	311·25	44·291	609·67	452·75	0·3365	1345·34	21 66	0·9375	4·295	2·963	·2329
5 5	4180	165	56837·0	80·833	155·85	312·53	44·342	609·84	452·19	0 3308	1367·00	21·66	0·3318	4·222	3·014	·2369
5·6	4256	168	57870·4	82·301	156 54	313·77	44·391	610·00	451·64	0·3252	1388·66	21·58	0·3262	4·151	3·066	·2410
5·7	4332	171	58903·8	83·773	157·22	315·00	44·439	610·16	451·11	0·3199	1410·24	21·49	0·3209	4·083	3·116	·2449
5·8	4408	174	59937·2	85·241	157·90	316·22	44·487	610·32	450·57	0·3147	1431·73	21·47	0·3157	4 017	3·168	·2490
5·9	4484	177	60970·6	86·710	158·56	317·40	44·534	610·47	450 05	9·3097	1453·20	21·39	0·3107	3·954	3·219	·2530
6·0	4560	180	62001·0	88·182	159·22	318·60	44·580	610·63	449·53	0·3048	1474·59	21·34	0·3058	3 891	3·270	·2570
6·1	4636	183	63037·4	89·652	159·87	319·77	44·656	610·78	449·02	0·3002	1495 93	21·33	0·3012	3·833	3·320	·2609
6·2	4712	186	64070·8	91·121	160·50	320·90	44·670	610·93	448·52	0·2956	1517·26	21·18	0·2966	3·774	3·371	·2649
6·3	4788	189	65104·2	92·591	161·14	322·05	44·715	611·08	448·02	0·2912	1538·44	21·21	0·2922	3·718	3·422	·2689
6·4	4864	192	66137·6	94·261	161·76	323·17	44·759	611·22	447·53	0·2869	1559·65	21·16	0·2879	3·663	3·472	·2729
6·5	4940	195	67171·0	95·731	162·37	324·27	44·801	611·37	447·05	0·2828	1580·81	21·06	0·2838	3 611	3·523	·2769
6·6	5016	198	68204·4	97·000	162·98	325 36	44·844	611·51	446·57	0·2788	1601·87	21·03	0·2798	3·560	3·574	·2809
6·7	5092	201	69237·8	98·470	163·58	326·54	44·886	611·65	446·10	0·2749	1622·90	20·97	0·2759	3·511	3·624	·2848
6·8	5168	204	70271·2	99·940	164·18	327·70	44·928	611·79	445·62	0·2711	1643·87	20·95	0·2721	3·462	3·674	·2887
6·9	5244	207	71304·6	101·409	164·76	328·57	44·968	611·93	445·17	0·2674	1664·82	20·88	0·2684	3·415	3·725	·2927
7·00	5320	210	72338·0	102·879	165·34	329·61	45·008	612·06	444·71	0·2638	1685·70	51·96	0·2648	3·369	3·776	·2967
7·25	5510	217·5	74921·5	106·553	166·77	332·19	45·108	612·40	443·58	0·2553	1737·66	51·72	0·2563	3·261	3·902	·3066
7·50	5700	225	77505·0	110·228	168·15	334·67	45·203	612·72	442·49	0·2473	1789·38	51·41	0·2483	2·159	4·027	·3165
7·75	5890	232·5	80088·5	113·902	169 50	337·10	45·296	613·04	441·43	0·2398	1840·79	51·17	0·2408	3·064	4·152	·3263
8·00	6080	240	82672 0	117·576	170·81	339·46	45·386	613·34	440·40	0·2328	1891·96	50·84	0·2338	2·975	4·277	·3361
8·25	6270	247·5	85255·5	121·350	172·10	341·78	45·475	613·64	439·38	0·2261	1942·80	50·64	0·2271	2·890	4·403	·3460
8·50	6460	255	87839·0	124·924	173·35	344·03	45·560	613·94	438·39	0·2199	1993·44	50 41	0·2209	2·811	4·527	·3558
8·75	6650	262·5	90422·5	128·595	174·57	346·23	45·643	614·22	437·43	0.2140	2043·85	50·10	0·2150	2·736	4·651	·3655
9·00	6840	270	93006·0	132·273	175·77	348 39	45·725	614·50	436·49	0·2084	2093·95		0·2091	2·665	4·775	·3753

(TABLE CONCLUDED.)

Pressure in					Temperature.								Volume.		Density.	
Atmospheres.	Millimetres of Mercury.	Inches of Mercury.	Kilogrammes per square metre. p	Lbs. avoirdupois per square inch.	Centigradial. t	Fahrenheit.	Quantity of steam converted into work during the production of steam. $A p u$	Heat of steam. J	Latent internal heat. ρ	Values of u.	Values of $\frac{\rho}{u}$.	Differences.	Volume of one kilogramme of steam in cubic metres. v	Corresponding volume of 1 lb. avoirdupois in cubic feet.	γ Weight of 1 cubic metre in kilogrammes.	Corresponding volume of 1 cubic foot in lbs.
9·25	7030	277·5	95589·5	135·947	176·98	350·49	45·804	614·78	435·56	0·2032	2143·85	49·90	0·2042	2·598	4·897	·3848
9·50	7220	285	98173·0	139·622	178·08	352·54	45·881	615·05	434·67	0·1981	2193·56	49·71	0·1991	2·534	5·023	·3947
9·75	7410	292·5	100756·5	143·260	179·21	354·53	45·957	615·31	433·78	0·1934	2242·94	49·38	0·1944	2·474	5·144	·4043
10·00	7600	300	103340·0	146·970	180·31	356·56	46·031	615·57	432·91	0·1889	2292·16	49·22	0·1899	2·416	5·266	·4138
10·25	7790	307·5	105923·5	150·644	181·38	358·48	46·103	615·82	432·07	0·1845	2341·25	49 09	0 1855	2·360	5·391	·4237
10·50	7980	315	108507·0	154·319	182·44	360·39	46·174	616·07	431·23	0·1804	2390 03	48·78	0·1814	2·308	5·513	·4333
10·75	8170	322·5	111090 5	157·993	183 48	362·26	46·243	616·42	430·41	0·1765	2438 62	48·59	0·1775	2·259	5·634	·4428
11·00	8360	330	113674·0	161·667	184·50	364·10	46·311	616·55	429·61	0·1727	2487·01	48·39	0·1737	2·210	5·757	·4524
11·25	8550	337·5	116257·5	165·341	185·51	365·92	46·379	616·79	428·81	0·1691	2535·11	48·10	0·1701	2·165	5·879	·4620
11·50	8740	345	118841·0	169·016	186·49	367·68	46·444	617·01	428·04	0·1657	2583·18	48·07	0·1667	2·121	5·998	·4714
11·75	8930	352·5	121424·5	172·690	187·46	369·43	46·508	617·34	427·27	0·1624	2631·00	47·82	0·1634	2·079	6·120	·4810
12·00	9120	360	124008·0	176·364	188·41	371·14	46·571	617·46	426·52	0·1592	2678·66	47·66	0·1602	2·039	6·242	·4905
12·25	9310	367·5	126591·5	180·038	189·35	372·83	46·633	617·68	425·78	0·1562	2726·08	47·42	0·1572	2·000	6·361	·4999
12·50	9500	375	129175·0	183·713	190·27	374·47	46·693	617·90	425·06	0·1533	2773·38	47·30	0·1543	1·963	6·481	·5093
12·75	9690	382·5	131758·5	187·387	191·18	376·12	46·753	618·11	424·34	0·1504	2820·47	47·09	0·1514	1·927	6·605	·5191
13·00	9880	390	134342·0	191·061	192·08	377·74	46·812	618·32	423·63	0·1477	2867·32	46·85	0·1487	1·892	6·725	·5285
13·25	10070	397·5	136925·5	194·735	192·96	379·33	46·869	618·53	422·94	0·1451	2914·11	46·79	0·1461	1·859	6·845	·5379
13·50	10260	405	139509·0	198·409	193·83	380·89	46·926	618·73	422·25	0·1426	2960·66	46·58	0·1436	1·827	6·964	·5473
13·75	10450	412·5	142092·5	202·084	194·69	382·32	46·982	618·94	421·59	0·1402	3007·22	46·53	0·1412	1·797	6·982	·5566
14·00	10640	420	144676·0	205·758	195·53	383·95	47·037	619·14	420·91	0·1378	3053·39	46·17	0·1388	1·766	9·305	·5662

the temperature from t to t_1, will be

$$Q = M(q_1 - q) + m_1 \rho_1 - m \rho.$$

By substituting for the values of q, q_1, and m_1, those given by equations (10) to (12), we shall have

$$Q = M c (t_1 - t) + m u \left(\frac{\rho_1}{u_1} - \frac{\rho}{u}\right).$$

Supposing, now, Q_0 to denote the quantity of heat that passes through the boiler in every unit of time, we shall have for τ minutes during which the temperature rises from t to t_1, and the pressure from p to p_1:

$$\tau = \frac{Q}{Q_0} = \frac{1}{Q_0}\left[M c (t_1 - t) + m u \left(\frac{\rho_1}{u_1} - \frac{\rho}{u}\right)\right], \qquad . (13.)$$

By this equation the problem is completely solved. It is obvious that the coefficient $M c (t_1 - t)$ will represent a much larger number than $m u \left(\frac{\rho_1}{u_1} - \frac{\rho}{u}\right)$, the weight of the water in the boiler being always by far larger than the weight of steam therein. The increase of the temperature $t_1 - t$, will therefore be proportionate to the time τ, as has been confirmed by the investigations of Mr. Fairbairn, and lately by Prof. Von Burg, of Vienna, in his paper "On the Efficacy of Safety Valves."* The formulæ given heretofore also coincide with the results of Mr. Fairbairn's experiments.

We shall illustrate the above by a numerical example. Supposing a steam boiler to have a heating surface of 18 square metres, (194 square feet,) and a capacity of 11 cubic metres, (388·5 cubic feet,) these dimensions will correspond to those of a boiler for an engine of about 15 H. P. This boiler will yield 7·5 kilos. (16·5 lbs. avoirdupois) of steam per minute, by the usual heating process. Supposing the average pressure of the steam to be four atmospheres, (58·788 lbs. per square inch), the temperature of water and steam will be $= 144°$ C. $= 291{\cdot}20°$ F.

In order to generate steam at a constant pressure, we must supply to each kilogramme of feed water of 0° C. introduced in the boiler a quantity of heat

$$J + A p u = 607{\cdot}06 + 43{\cdot}49 = 650{\cdot}55 \text{ units of heat.}$$

At the moment the temperature of water reaches 15° C., the quantity of heat to be supplied will be

$$650{\cdot}55 - 15 = 635{\cdot}55 \text{ units (calories).}$$

The boiler yielding 7·5 kilos. of steam pr. 1″, the quantity of heat to be supplied to the boiler pr. 1″ will be

$$Q_0 = 7{\cdot}5 \times 635{\cdot}55 = 4766{\cdot}62 \text{ calories.}$$

Supposing, now, the egress of the steam to be stopped, while the same quantity of heat, Q_0, continues to be supplied to the boiler by means of the heating process, the question arises in what time the pressure of four atmospheres will have increased to eight atmospheres, provided six-tenths of the capacity of the boiler be filled with water,

* See "Sitzungsberichte der Wiener Akademie," vol. xlv, page 313.

and four-tenths with steam of four atmospheres, at the moment the egress of steam is interrupted.

The capacity of the boiler being $V = 11$ cubic metres, the weight of the water it contains will be

$$0{\cdot}6 \times 11 \times 1000 = 6600 \text{ kilos.}$$

By the table, the weight of a cubic metre of steam at four atmosphere pressure is $= 2{\cdot}237$ kilos.; therefore

$$m = 0{\cdot}4 \times 11 \times 2{\cdot}237 = 9{\cdot}84 \text{ kilos.}$$

The aggregate weight of water and steam combined will be, therefore,

$$M = 6600 + 9{\cdot}84 = 6609{\cdot}84 \text{ kilos.}$$

The coefficients of formula (13) will be, for the original pressure of four atmospheres,

$$t = 144^\circ\,;\ u = 0{\cdot}4461\,;\ \frac{\rho}{u} = 1034{\cdot}62\,;$$

and for a pressure of eight atmospheres,

$$t_1 = 170{\cdot}81\,;\ \frac{\rho_1}{u_1} = 1891{\cdot}96.$$

Substituting these values, we have

$$M\,c\,(t_1 - t) = 181{,}179{\cdot}2$$

$$m\,u\left(\frac{\rho_1}{u_1} - \frac{\rho}{u}\right) = 3763{\cdot}3\,;$$

and as $Q_0 = 4766{\cdot}62$, we find

$$\tau = \frac{181{,}179{\cdot}2 + 3763{\cdot}3}{4766{\cdot}62} = 38{\cdot}80 \text{ minutes;}$$

i.e., in a boiler worked under the above conditions, the pressure of steam will require 38·8 minutes to rise from four to eight atmospheres.

Supposing, on the other hand, the volume of water in the boiler to be less than that of the steam, at the moment the egress of the latter is stopped, say, *e.g.*, the proportion to be water : steam : : 0·4 : 0·6, the weight of the steam would be

$$m = 14{\cdot}76 \text{ kilos.,}$$

and water and steam combined

$$M = 4414{\cdot}76 \text{ kilos.;}$$

and to raise the pressure from four to eight atmospheres, we should then require a lapse of time

$$= 26{\cdot}57 \text{ minutes,}$$

i.e., 12·23 minutes less than in the former instance.

The following table exhibits the values of the several coefficients for the same boiler, for pressures varying from four to twelve atmospheres.

This table shows that the inference drawn by Councillor von Burg from Mr. Fairbairn's experiments, viz: that the temperature in the boiler increases in proportion to the time, is perfectly justified. The speed with which the pressure in a closed boiler increased will depend on the quantity of water in the same; the less water there is, the more

the pressure will increase, and with it the liability to explode. All this corroborated Bernouilli's opinion, that the quantity of water in the boiler is the real standard of the pressure of the steam.

Pressure in Atmospheres.	Temperature in degrees Centigrade.	Differences, $t_1—t$.	Volume of Water in the Boiler. 0·6 v. Lapse of time τ''.	0·6 v. Differences.	0·4 v. Lapse of time τ''.	0·4 v. Differences.
Original 4	t = 144·00	. .	. .	. .	. .	. .
5	t_1 = 152·22	8·22	11·86	11·86	8·09	8·09
6	159·22	15·32	21·97	10·11	15·01	6·92
7	165·34	21·34	30·85	9·88	21·11	6·10
8	170·81	26·81	38·80	7·95	26·57	5·46
9	175·77	31·77	46·02	7·22	31·55	4·98
10	180·31	36·31	52·64	6·62	36·12	4·57
11	184·50	40·50	58·76	6·12	40·36	4·24
12	188·41	44·41	64·48	5·72	44·32	3·96

Mont Cenis Tunnel.

From the London Practical Mechanic's Journal, August, 1865.

Pending the completion of the tunnel of 7½ miles through Mont Cenis, and which, as more than 4½ miles remain to be pierced, will yet require seven or eight years, Messrs. Brassey have taken steps towards the construction of a railway over the mountain, to supply the break of 47 miles now existing between St. Michel and Susa in the line of communication between France and Italy. The French government have promised a concession for the work on their side of the mountain, on the condition of its practicability being demonstrated, and the Italian government have undertaken to grant what is required on their side. An experimental line has accordingly been already constructed on the French side between Lanslebourg and the summit—a distance of a mile and a quarter—and Captain Tyler, of the Royal Engineers, was recently deputed by the Board of Trade to visit it and report the results. That report has now been printed, and its conclusions are of a very favorable character. It describes the experimental line to possess a mean gradient of 1 in 13, and a *maximum* of 1 in 12. It passes round a sharp corner, joining two of the zigzags of ascent on a curve with about two chains radius, and was purposely constructed on the most difficult portion of the route. Captain Tyler, in two days, took six trips with the engine up and down, carrying each time a load of 16 tons in three wagons, including the weight of the wagons, and it performed the ascent in 8½ minutes. Mr. Fell,

by whom the work has been carried on under estimates framed by Mr. Brunlees, C. E., has thus "shown practically that gradients of 1 in 12 to 1 in 15 may, by a system of horizontal driving wheels acting upon a middle rail, be substituted for 1 in 25 and 1 in 30, which have hitherto been practicable, and that sharper curves may also by this system be more safely worked," or, in other words, "that a railway may be constructed over a given summit of half the length that would otherwise have been necessary, and at less than two-thirds the cost." In the present case, the cost of the temporary line is to be £320,000, or about £6720 per mile, whereas the tunnel line is expected to cost £5,400,000, or £128,500 per mile. Even the cost of a permanent and independent summit line, with a wider gauge and better curves, would not exceed £20,000 per mile. The importance of these results to the future of railway construction in mountainous countries can therefore hardly be over-estimated. No pecuniary aid has been asked either from the French or Italian governments, Messrs. Brassey feeling certain of a sufficient profit from the natural traffic at the tariff which has been provisionally sanctioned. The road traffic between the two points yielded, in 1864, £76,000, and it steadily increases at the rate of more than 10 per cent. per annum. This, without estimating any higher rate of increase after the opening of the railway, would yield in seven years a total revenue of £1,080,000, and "it is considered that such a revenue would leave at the end of that time a clear profit of seven millions of francs, after deducting all charges, and after paying interest upon and paying off the total bond and share capital of £320,000. But as the great saving of time, combined with the agreeableness of the passage, would inevitably promote a great accession of travel, and it is calculated, moreover, that 38 hours may be saved by this work in the transmission of the Indian mail, prospects much more gratifying may fairly be assumed. "In conclusion," Captain Tyler states, "I have to report as the results of my observations and experiments, that the scheme for crossing the Mont Cenis is in my opinion practicable, both mechanically and commercially, and that the passage of the mountain may thus be effected not only with greater speed, certainty, and convenience, but also with greater safety than under the present arrangements."

On Marine Engines from 1851 *to the Present Time.*

By N. P. Burgh, Esq., Engineer.

From the Journal of the Society of Arts, No. 643.

The history of the origin of the marine engine, and its slow advance, has been so often written, that I feel assured I shall not cause much disappointment if I pass over that already worn-out subject. I propose, therefore, to introduce to your notice the marine engine as it was in 1851, and the improvements which have taken place from that period to the present time. As the present paper alludes to the year

1851, it will not be deemed out of place to describe briefly the marine engines shown in the Exhibition of that date. The screw propeller was then making but slow progress, consequently the attention of our engineers was diverted from straining their talents to produce more perfect arrangements. The following examples of marine engines were exhibited :

For the paddle-wheel, the engines were arranged as follows: Vertical, angular or inclined, direct-acting, and oscillating; for the screw propeller, a more varied and numerous collection was given, comprising disk, rotary; for horizontal direct-acting types, were the following: double piston rod, return connecting rod, trunk; after which, annular cylinder, vertical direct-acting, inclined direct-acting, single piston rod; and lastly, a beam engine. The largest pair of engines were 700 horse power collectively, horizontal, direct-acting, single piston rod. The trunk engines were 60 horse power collectively; these two examples were adapted for the screw. For paddle-wheels, the engines of the greatest power were a pair of 140 horse power, of Belgian repute, the framing and paddle-centres being of wrought iron, thus ensuring sufficient strength with a reduction of material and weight. To describe each engine in detail would be tedious, as well as of little value to the engineer of the present day. Allusion to the defects and improvements will be found under the different descriptions of the necessary appendages.

I now proceed with a brief notice of the marine engines exhibited in the year 1862, when it will be seen that a great improvement had taken place between the two dates alluded to. We are, I am happy to state, still making an advance, and I trust to be able this evening to describe these improvements; but, at the same time, I beg to suggest that there is plenty of room for further improvement in the detail of marine engines, which, doubtless, will be ere long taken into consideration by those interested in these matters.

In the year 1862, our International Exhibition was again held, and with much success as far as regards marine engines. The class exhibited showed great improvement, both in design and arrangement. The oscillating engines adapted for the paddle-wheel did not exhibit much alteration, although it cannot but be said that in detail a change for the better was perceptible. With reference to the engine adapted for the screw, a complete revolution had taken place since the Exhibition of 1851. Valves and gear were altered, starting gear simplified; position of condensers, air pumps, and valves, in a much more correct state; number of details lessened; and, in fact, the entire arrangement fast approaching to a nearer state of perfection, viz: accessibility to all the parts in action without disarrangement. The following is a brief account of the writer's observation of the class of marine engines exhibited: The paddle engines were vertical and inclined, oscillating, of the ordinary type and arrangement. The valve gear was of two kinds—the counter-balanced eccentric, and the ordinary link motion. The air pumps were worked by eccentrics in some instances, and in others by cranks. The mode of starting was by the

ordinary ratchet or wheel and pinion—the bilge and feed pumps were, in some cases, worked by the oscillation of the cylinder, and in others by eccentrics. The means for disconnecting were of the disk and the drag-link kinds. Paddle-wheels were exhibited with fixed and feathering floats. Five examples of oscillating engines were exhibited, including models and drawings. The engines for the screw propeller were as follows: One pair of double trunk engines, having injection condensers with an improved arrangement of air-pumps and valves. The double piston rod, return connecting rod type was well represented; this arrangement is used on account of the great length of stroke and connecting rod attainable in a given space. In the Exhibition now alluded to there were six pairs of engines of this class, with injection condensers and air pumps of the ordinary arrangement, and one pair of engines with the improved arrangement of condensers, pumps, and valves. The single piston type of engine was not largely represented—one pair with the improved injection condenser, pumps, and valves, and one pair with those of the ordinary kind. The single trunk arrangement was represented by one pair, with single acting trunk air pumps in the condensers. The air-pump trunk with double piston rods return connecting rod engine was shown by drawings only. Vertical direct-acting engines were represented thus—one pair with annular cylinders, double piston rods, and injection condensers of the ordinary kind; one pair with single piston rods and surface condensers; and another pair as the last, with ordinary condensers.

It will be understood that in the previous examples the cylinders were arranged in pairs, the cranks being at right angles. In order to obviate the strains imposed at the extremity of each stroke, one firm exhibited engines with three cylinders, with spur gearing for reversing, stopping, &c., which were termed the expansive and economical principle. Lastly, I allude to the writer's invention "Burgh and Cowan's patent antifriction trunk engine," so arranged, that the friction of the trunks is dispensed with, and no area lost in the cylinder. This arrangement was represented by a pair of engines and drawings. Having thus briefly alluded to the marine engines exhibited in the two International Exhibitions of 1851 and 1862, I will now proceed to give a detailed description of each portion.

The arrangement of marine engines in the hold of the ship is, perhaps, not generally thought to be of so much importance as it really is. It should be strictly understood that the attention required for engines of river steamers bears no comparison with that required for marine engines. Imagine a ship in a gale, and heated bearings, and a faint idea can be formed of the duties required, and the reason for a free access to all the working parts.

For the purpose of illustration to those present, not professional engineers, I will briefly specify what the necessary component parts of a pair of marine engines of the present day consist of, viz: cylinders, pistons, slide valves, piston rods, slide casings, expansion valves, blow-through valves, piston rod guides, connecting rods, cross-heads, main frames, crank-shaft, eccentrics, rods, links, valve rods, guides,

condensers, air pumps and valves, injection valves, shifting valves, discharge valves, bilge and feed pumps, valves for the same, starting gear and turning gear, lubricators, and all the necessary levers, bolts, nuts, &c. It will thus be seen that marine engineers have more difficulties to contend with than is generally known. To understand the use and real character of each of the above details is not the work of weeks or months, but years. It should not be forgotten either, that the honor of our nation, and the lives of its representatives, are often in the hands of the marine engineer. I will now proceed with the descriptive illustration of details, showing defects, improvements, and suggestions for the future, commencing with slide valves.

These valves govern the entrée and exhaust of the steam to and from the cylinders. Two kinds or classes of valves are now universally used, the common and the equilibrium; the former is so well known that a description of it is scarcely necessary. I will only observe that its use for larger engines is much on the decrease, on account of the stroke of the valve being due to its outside lap, which for large ports is considerable. Equilibrium valves are so called from the equal action of the steam tending to lift the valve from, as well as to press it on its facing. These valves are double ported to reduce the stroke. One firm has lately introduced three-ported valves, to still further reduce the stroke. In order to reduce the friction of the valves on the facings, rings are used encircling the body of the valve, adjustment being gained by screws, ratchets, and springs to prevent looseness. In some cases a communication from the back of the valve to the condenser is arranged to still further reduce the pressure on the valve facing. Slide rods are usually one to each valve, but latterly two have been introduced for large valves, which no doubt greatly assist in güiding the valve during its action.

The next portion in rotation will be that for working, reversing, and stopping the action of the slide valve universally known as the "valve link motion." The date of the origin of this motion is doubtful. Mr. Zerah Colburn, in his new work on locomotive engineering, tells us, however, that 1832 is the earliest period of its application for locomotives. Marine engineers introduced it first for oscillating paddle wheel engines; afterwards for fixed, horizontal, and vertical engines adapted for the screw propeller. The object of the link motion is to reverse the action of the slide valve without disconnexion. The links now in use are of two kinds—slotted and solid. The slotted link has the sliding block within it, whereas that of the solid kind slides within the block. The means adopted for raising and lowering the link are various. One maker prefers to use a lever, secured on a weigh-shaft, passing over the front part of the cylinders, motion being given by a worm and wheel, the former being keyed on or forming part of the starting wheel shaft. Another firm deems it better to impart motion to the lever by a ratchet and pinions. A third authority raises and lowers the link by a rod connected to a block surrounding a coarsely pitched screw, motion being given to the screw by mitre gearing; whilst another firm prefers to fix the block, with the screw

to be elevated and lowered. These two last are undoubtedly the most powerful of the examples given.

The systems at present adopted for guiding the slide valve rod are of three kinds. First, the dove-tailed guide, similar to that used by tool makers for the arm of a shaping machine. Second, a block of gun metal sliding on two fixed turned rods as guides over and under the valve rod. Third, the valve rod secured to a square bar, working in a bracket, and cap to correspond. This last may be said to be the most simple, but perhaps not so rigid as the first example. The double guides are complicated, but at the same time produce the rigid resistance to the strains imposed on the valve rod by the vibration of the link.

Some makers of marine engines prefer to allow the link to rest or hang on the block pin inserted in the lever of the slide rod weigh-shaft. Such a practice dispenses with guides. Excessive vibration of the link on or in its block greatly deteriorates the action of the valve, it being understood that whilst the link has an ascending or descending motion, as well as sliding, the strain on the valve rod is increased, and at the same time the stroke is effected. The excess of the vibratory motion is painfully perceptible in the ordinary slotted link; the eccentric rods being connected beyond the block pin, a direct-action cannot ensue. The distance between the centres of the eccentric rods and block regulates the amount of indirect action. Links of this kind are often hung from a rod connected in the centre to the link, either to the clip or at the back. This is far better than at the lower end, as the connexion of the suspension rod regulates the ascending and descending motion of the link whilst at work. The link resting on the block when for going ahead, obviates to a certain extent some of the evils alluded to. The gain by the introduction of the solid link, with the eccentric rods connected at its extremities, is strength with less material, but the vibrating motion is not decreased. In order to obtain a more direct, and, if possible, a perfect action, the eccentric rods have been secured to the link, so that the centre of connexion may be on that of the block, and by this the vibratory motion is effectually got rid of. There have been two distinct modes for accomplishing this, which I have had the opportunity of observing. The first example is—two solid links, one on each side of the block, the eccentric rods being connected to pins on the outer face of each link, the inner face and sides being sustained in a groove in the block, which oscillates on its axis, in the eye of the valve rod, the links being one on each side. The second example is like the first in principle, but one solid link only is used, of a dove-tailed form in section, at the inner face, to prevent the link from slipping out of the groove in the block; the eccentric pins are fixed in the extremities of the link, and the rods are attached as in the last example, but with a single eye. The writer has designed a solid link and connexion, which, although not superior in principle of action to the two last examples, is more simple in construction, and has less working portions; therefore it may be held to be worthy of introduction. A solid bar of iron is slotted

at each end, to receive the single eye of each eccentric rod, so that the entire surface of the link remains unbroken; it is secured in a block with an adjusting portion and key at the back, the front being open sufficiently to admit of the ascent and descent of the eccentric rods; adjustment in front can be obtained by loose portions and set-screws, but this last is not imperative, as the wear of the link and block is very slight when the acting eccentric rod is on the centre of the block; the block has provisions on each side for suspension, the valve rod having portions formed to receive the block; the back part of the rod works in a dove-tailed guide of the ordinary kind.

It now becomes necessary to treat of the suspension or lifting rods for solid links; for this a few words will suffice. As the ascent and descent of the link whilst in motion are governed by the length and position of the rod, it is almost needless to state that the suspension rod should be connected in the centre of the connexion of the eccentric rod. The link, when for going ahead, should be down. It may now be argued that the vibration of the link, when for going astern, must be excessive. Granted; but as the forward motion of the ship is of the most importance, it is not unfavorable to economy to adopt the connexion alluded to. In some cases the solid link is guided at the top or bottom, but this is only required when an overhanging or outside connexion of the eccentric rods is resorted to.

The next portion for consideration is the expansion valve and gear; the use of this valve is to allow the steam to be cut off at the early or given part of the stroke of the piston, and the expansion or elasticity of the steam completes the power required. Now, it is certain that the use of high pressure steam for large cylinders and short strokes, produces excessive shocks at the commencement of the strokes, and thereby entails an increase of strength in the materials used, so that the proportions are larger than when for ordinary purposes. It is clear also that, when steam is admitted at an excessive pressure against the piston suddenly, it (the piston) receives an impetus equivalent to the power imposed, and in no case whatever could an engine of proportions for low pressure resist the strains imposed by the use of high pressure steam. The ordinary pressure adopted by marine engineers is from 20 to 30 lbs. per square inch, more often the former than the latter. I am not aware, however, of any cause why 60 to 80 lbs. should not be adopted, with a great increase of economy and power. Of course, the present proportions of engines and boilers would have to be increased, if the same materials were used, but steel boilers, shafts, and rods might be introduced with considerable advantage, embracing great strength with less weight.

Having alluded to the ordinary pressures at present used, it will be well now to advert to the expansion valves. These valves are of three kinds—throttle, slide, and tubular.

The motions imparted to the throttle valve are oscillating and revolving. The latter is now most generally adopted, but with this disadvantage, that the action is equal both for supply and cutting off.

The slide valves are of the ordinary and gridiron type, the latter may

be said to be the better on account of the stroke being so short in comparison to that of the former.

Tubular valves are tubes inserted in each other, with ports to correspond, a sliding or rotary motion accomplishing the desired effect. The motions imparted to these several valves are generally uniform, either by mitre gearing or eccentrics, consequently the action of the valves is not perfect. The proper motion for an expansion valve is to open gradually and close suddenly ; to obtain this the old but correctly working cam must be resorted to ; this useful arrangement is too often discarded to make place for newer but less correct productions. It may, of course, be urged that the cam is not applicable for high velocities, but undoubtedly its use might be attained by introducing stiff gear and perfect equilibrium double beat valves ; by dividing this valve centrally a more correct action can be attained, in relation to that of the steam, on the valve whilst closed and open. The merits and demerits of the expansion valves here alluded to are almost equal. The ordinary throttle valve has less friction than any yet introduced, but it possesses the great evil of throttling the steam when closing ; also when this valve is worked by levers, or has a vibratory motion, should the stroke be lessened, the full area cannot be attained. The last evil is dispensed with in the remaining example, as the ports or openings are much larger than required when the valve is at full stroke, and not too small when the least motion is given. The friction of the gridiron valve is perhaps in excess of the other examples, as in the case of the tubular valves, the action of the steam is neutralized. The means adopted for altering the grades of expansion valves whilst in motion are various. A spiral motion is the one universally adopted, and there is not the least doubt it is correct.

I will now call attention to the following description of an expansion valve and gear which I have designed for high velocities : A cylindrical casing has within it projections at given positions ; two of these projections act as spaces between the ports of ordinary tubular valves. The valve now explained is tubular, but the area centrally is half of that of the ends, which are parallel for given lengths, due to the stroke of the valve. These parallel lengths also regulate the neutrality of the valve whilst in action. At the present time the means adopted to impart the motion is a disk of metal with a circular slot ; within this slot is a brass nut into which is screwed a pin. The connecting rod of the valve is attached to the pin in the ordinary manner. The means for altering the grades of expansion is by loosening the pin by its handle, and allowing the nut to slide in the slot to the required position. It is almost needless to add that the steam enters at the side of the casing, and escapes around and through the valve, keeping it in equilibrium.

The valves next in requisition are those for the ends of the cylinder, commonly known as relief valves. The usual kinds adopted are disks, with springs or weights to resist the given pressure of the steam. The action of these valves is, of course, due to the excess of pressure within the cylinder over that of the resistance caused by the springs or

weights. It has been proved that in the case of excessive priming of the boilers, the cylinders are suddenly flooded; in order to release the water, cocks are sometimes used, but in many instances the springs or weights are lifted by levers. Now, in the case of cocks, if not provided with valves beyond them they must be worked by hand at each return stroke of the engine, or the vacuum will be destroyed. The spring valves will close naturally, or by the spring on its release from the hand lever. High pressure steam has been lately introduced, with great advantage, in the place of springs, but with an entirely differently arranged valve and casing.

I have arranged a relief valve, so that the spring is not tampered with by levers or hand power, and an instantaneous opening can be effected without cocks, &c. The spring valve has an opening in it centrally to receive on its outer side a flat disk, termed the vacuum valve. On the inner side is a provision mitred to receive a solid disk valve, which, on being pressed inwards by a spindle and lever, allows a free exit for the steam and water. On a vacuum being caused the vacuum valve, which is guided on the spindle alluded to, closes the opening air-tight; by this it will be understood that the spring has not been in requisition, but on closing the inner disk the spring valve becomes one of the ordinary kind. Previously to starting the engines it is well known a vacuum should be caused in the condensers, also the cylinders and slide casings should be warmed, and the condensed water be allowed to escape through the relief valves and cocks.

The valves used for the purpose alluded to are termed the "blow-through valves." It may be here observed that, in some cases, the ordinary plug-cock is preferred for this purpose. When valves are introduced, they are generally of the ordinary disk kind, but one firm adopts a common slide valve for the purpose, with the advantage of simplicity of levers, &c., and easy manipulation.

The piston rods of marine engines are subject to excessive strain; consequently, the use of guides is imperative. For the single piston rod engine, the universal system is a channel underneath the rod, the guide block being generally of gun metal, and the upper portion attached to the piston rod by bolts and nuts. For double piston rod engines, the guides are of two kinds: the first arrangement is as the last, and the second, as for high pressure engines, or double guides. To say which is the preferable mode of arrangement of guides will perhaps be deemed bold, but I may venture to state that I deem that for the single piston rod the best of any yet introduced.

I cannot close this portion of the present paper without alluding to the admirable arrangement for tightening the gland of the piston rod stuffing boxes, introduced by the firm of Messrs. Maudslay, Sons & Field. The screws are of the ordinary kind, but, in the place of nuts, worm wheels are used, worms being fitted to correspond; and motion can be given by a box spanner while the engines are at work. This is one of the most important improvements tending to accelerate the progress of a ship during a voyage, say three or four months. Imagine the engines requiring stoppage during a gale in order to tighten

the glands, and a fair estimation can be formed of the value of the improvement alluded to.

Having commented, though somewhat briefly, on the cylinder appendages, attention may now be given to the main frames and crank shaft. The main frames may be said to undergo a continuous strain, and must, consequently, be of a certain strength in order to preserve the requisite rigidity. The cylinder is attached to the one end, and the condenser at the other, whilst the crank shaft has to be supported in its bearings. Not many years ago a celebrated firm used to make the condenser and main frame in one casing: since that, we have had the well known frame like the letter A laid on its side, also the hollow frame, with a raised projection for the crank shaft, and a stay from the upper portion connected to the cylinder; this last may be said to be the most simple, and, at the same time, of less material than the A frame. As before stated, the strains on the frames are continuous, yet, when sudden shocks occur, from the racing of the engines or priming of the boilers, the tenacity of the cast iron is severly tested. As this is the case, wrought iron might be used with great advantage, both as to increase of strength and decrease of weight. The crank shafts of marine engines are generally of wrought iron, in one mass, the cranks being double, and forged with the shafts. Three bearings are deemed imperative, so as to equally distribute the strains. Now, this is correct in theory and practice, and the writer will be deemed committing a grave error no doubt in mathematics, when he assumes that the forward frame and half crank can be dispensed with, in order to reduce the weight and material. He is, of course, aware that the thrust and pull of the connecting rod will be thrown on the centre crank and bearing, but, in order to counteract this, the length and diameter of the shaft at that part should be increased. He would also prefer, in this case, to extend the frame and connect the upper portion to the condenser, the cap being on the top instead of at the end, as now used. Screws might be employed to adjust the side brasses; the eccentrics could be within the cranks, or between them and the bearings.

(To be continued.)

Roof of the London Terminus of the Midland Railway.

From the London Mechanics' Magazine, June, 1865.

Up to the present time the roof of the Imperial Riding House, at Moscow, has held its place as the largest ever executed, its span being 235 feet. But we understand that it is contemplated to cover in the London terminus of the Midland Railway with a roof of wrought iron 240 feet clear span. It will be of an arch construction, springing from the level of rails, and having a versed sine of about 100 feet. When built, this roof will, therefore, rank as the largest of one span in the world.

Prevention of Railway Collisions.

From the London Athenæum, June, 1865.

Under the excitement caused by recent railway accidents, in one of which literature only just escaped from a fearful loss, the traveling public will learn with much satisfaction that an experienced officer of the London and North Western Railway has adapted and is now carrying out a plan by which it is hoped that collisions, at least, may be prevented. This officer is Mr. S. M. Martin, the Telegraphic Engineer of the Company; and his plan consists, mainly, in establishing a series of permanent currents of electricity in connexion with the telegraph by which an interval of space may be secured between trains traveling in the same direction. At every station, level crossing, and siding, there are telegraphic instruments by which a signal man may be informed of the approach of every train in either direction. Nothing is left to the signal man's memory, capacity, or discretion. The telegraph puts the fact before him on the dial. He has only to read and act. To make the matter perfectly easy, only three signals are used, namely, "Train on line," "Line clear," "Line blocked." So long as a train is approaching a station, the signal "Train on line" is permanently indicated on the dial before the officer's eyes. In the event of a train coming to a stand-still between any two stations from any cause, it is the duty of the guard, or other person in charge of the train, to leap down and sever the current wire, which is conveniently placed within his reach at every second post. The permanent current being stopped, the signal man is made aware of it by his dial reporting "Line blocked." Measures may then be taken accordingly. It is stated that this plan is so simple that no previous instruction is required in order to work it. Anyhow, it is clearly a plan which deserves attention from all railway directors and officers; all the more from the fact that it is already in operation over the major portion of the London and North Western line.

New Steam Engine.

From the London Mechanics' Magazine, February, 1865.

An addition has just been made to the plant of the Lambeth Distillery Brigade in a new steam fire engine, made by Merryweather, called the "Ocean Wave," which is perhaps the most powerful machine of the kind in the world. The weight is $2\frac{1}{4}$ tons, and it is said to get up steam in eight minutes, and to discharge six jets of water to a distance of 220 feet.

New Zealand Coal Mines.

From the London Mechanics' Magazine, February, 1865.

In the province of Auckland, New Zealand, mines are being worked which yield a coal of superior character to English coal. It requires one hour forty-five minutes to raise steam by means of the best New-

castle coal, whilst by that from Kawakawa mine, at the bay of Islands, in the above province, steam is stated to be raised in one hour five minutes.

Average Consumption of Coal per Horse Power.

From the London Mechanics' Magazine, June, 1865.

The present average consumption of coal in Her Majesty's steamers is 3·5 lbs. per indicated horse power per hour, but with the improvements recently effected in the machinery of the "Arethusa," the "Octavia," and the "Constance," (which improvements have in view the obtaining of correct data with regard to the comparative consumption of coal,) confident anticipations are formed that the consumption will be one-third less, or 2·5 lbs. per actual horse power per hour.

MECHANICS, PHYSICS, AND CHEMISTRY.

On Chemistry Applied to the Arts. By Dr. F. Crace Calvert, F.R.S., F.C.S.

From the London Chemical News, No. 244.

(Continued from page 194.)

Lecture IV.

Animal Fatty Matters, the various processes for liberating them from the tissues in which they are contained. Their composition and conversion into soap. Composite candles. The refining of lard. *Cod liver*, *Sperm*, and other oils. *Spermaceti* and *wax*.

I have now to draw your attention to a totally different kind of manufacture, viz: that of composite, stearic, and Belmont candles. Many years elapsed between the scientific discovery by M. Chevreul of margaric and stearic acids, and their application to illuminating purposes; for it was early in 1825 that MM. Chevreul and Gay Lussac took out a patent with a view of realizing this advantage. But it was reserved for a manufacturer, M. de Milly, to perfect the manufacturing details of the processes, and to render these candles a marketable commodity. This he affected by also improving the manufacture of the wicks, and he was the first to introduce this article to the trade in 1832, under the name of *bougies de l'etoile*. Let me give you an idea of his *modus operandi*. 100 lbs. of tallow, 17 lbs. of lime previously slaked, and 1000 lbs. of water were placed in a large iron boiler, and kept at the boil for several hours by means of a jet of steam. The result was that the glycerine dissolved in the water, whilst the fatty acids united with the lime. The indissoluble stearate, oleate, and margarate of lime were then decomposed by weak vitriol, under the influence of heat. Insoluble sulphate of lime was produced, and the fatty acids liberated. These, in their turn, were submitted to hot and cold pressure, which liberated the oleic acid, leaving the solid stearic and margaric acids

behind; it was then only necessary to cast them into moulds containing wicks, and the *bougies de l'etoile* were produced. MM. de Milly and Motard have introduced of late years several important improvements into this branch of manufacture, the most important of which is that of operating under pressure, by which means they succeed in decomposing the fatty matters with 3 or 4 per cent. of lime instead of 17, this, of course, involving the saving of a large quantity of vitriol. M. Bouis has made a further improvement by adding to stearic candles 3 or 4 per cent. of cebacic acid, which is extracted from castor oil, and has the high fusing point of 261 degrees. M. Chevreul also suggested a simple method of increasing the whiteness of these candles by the addition of a small quantity of ultramarine blue to neutralize the slightly yellow tint of the manufactured acid. One of the greatest improvements in the manufacture of these candles is that carried out by Price's Candle Company; but before describing to you this beautiful process, as adopted by Mr. G. F. Wilson, at this company's works, allow me to state a few facts. Up to 1840 the best kind of candles were those made of spermacceti or of animal fatty matters which were cold and hot pressed. In that year Mr. Wilson, whilst experimenting with the view of making candles which would not require snuffing, for the illumination on the occasion of her Majesty's marriage, discovered that a combination of cocoanut stearine with stearic acid would make candles giving a beautiful light, and free from the necessity of snuffing. These he called "composite," and they were soon largely sold. In 1838 M. Fremy published his interesting discoveries, showing that when oils or fatty matters were mixed with 20 or 30 per cent. of concentrated sulphuric acid, the fatty matters were split, or, as he calls it, saponified, and that sulpho-margaric, sulpho-stearic, sulpho-oleic, and sulpho-glyceric acids were formed. He further observed, that boiling water decomposed the sulpho-stearic and margaric acids, and only partially the sulpho-oleic into stearic, margaric, oleic, and sulphuric acids, which last acid remains in the water together with the sulpho-glyceric acid and that portion of the sulpho-oleic acid not decomposed, the other acids remaining insoluble and floating on the surface. In 1842, Messrs. G. Price and Jones secured a patent to carry out on a practical scale the scientific discoveries of M. Fremy. In that patent two or three important facts were brought out: First, that if, instead of operating at a low temperature, as recommended by Fremy, heat was employed, the action of the sulphuric acid on the organic compounds would give rise to sulphurous acid, which they discovered had the remarkable property of converting the liquid oleic acid into a solid acid called "eladic," thus largely increasing the yield of solid fatty acids. Their mode of operating was this: 10 to 12 per cent. of concentrated sulphuric acid was added to the fatty matters which had been previously liquefied by heat, and the whole was kept at a temperature of 200° for twenty-four hours. During that time the fatty matters were split into their primitive elements, and the oleic acid was converted into eladic acid. The whole was then repeatedly treated with boiling water, to dissolve the sulpho-glyceric acid and other impurities, leaving the solid

fats ready for distillation. Mr. G. F. Wilson has since then greatly improved this part of his manufacture, as the beautiful candles, everywhere to be seen, will amply prove. The most important improvement, in a chemical point of view, is the following: He has found, for example, that fatty matters are split up into their component parts by decreasing quantities of vitriol as the temperature used is increased. Thus, at a temperature of 100°, 15 parts of vitriol are required; at 350°, six parts; at 500, one part. Further, by employing this small proportion of sulphuric acid, not only is the expense of washing the fatty matters after their saponification by the acid avoided, but the distillation may be proceeded with in the same vessel. The distillation of fatty matters, first performed by Mr. Wilson, and since carried by him to a state of perfection, is based on the fact that, whilst fatty matters, if distilled by direct heat, are completely decomposed, giving rise to the noxious vapors of acroline, from the destruction of the glycerine, &c. This evil is completely avoided in distilling them by passing a current of superheated steam at a temperature of between 550° and 600° through the mass of melted fatty matters previously brought to the same temperature. By this means the glycerine passes first without decomposition, and is then followed by the fatty acids. In fact, the distillation proceeds with such rapidity and regularity that a stranger might witness the distillation of 1000 gallons in twenty-four or thirty-six hours, and all the time would probably suppose that water only was distilling. The results are so perfect, that the jury at the Paris Exhibition of 1855 could hardly credit their genuineness, and actually deputed Mr. Warren de la Rue to come from Paris to verify the fact that the beautiful products exhibited were obtained in many instances from very inferior kinds of fat. The glycerine only requires redistillation to be fit for all the purposes to which it is applied. As to the acids, they are submitted to an intense cold pressure, which separates the oleic acid from the stearic, margaric, or palmitic acids. These are melted, and when near the point of solidification, the vessel containing them is run on rails over the moulds, which are so arranged that each frame contains 200 separate moulds, in which already the wicks, prepared with borax or a salt of ammonia, are fixed. The only remaining operation is to fill the moulds and allow the candles to cool.

Oleic acid has recently been made available for several valuable purposes. It has been largely employed in the manufacture of soap; but its most important application as yet is its use on the Continent, and recently in England, as a substitute for olive oil in the greasing of wool for spinning, the advantages of which are marked, as its removal by alkalies in the scouring process is much easier and its price lower. Messrs. Laing and Wilson have recently taken out a patent for the employment of oleate of ammonia as a mordant; and, as the specimens which I have the pleasure to show you illustrate, it increases in a marked manner the beauty and brilliancy of the coal tar colors on cotton.

It now only remains for me to refer to another interesting process for splitting fatty matters into their elements, I mean that of M. Tilgh-

man, which consists in mixing fatty matters with one-third to one-half of their bulk of water, and placing them in a vessel capable of resisting a very high pressure. They are submitted to a temperature of between 550° and 600° Fahr., and under the influence of that heat and pressure the fatty matters are decomposed into glycerine and fatty acids. M. Tilghman has also adapted an apparatus which enables him by means of coils of tubes to keep up a constant stream of fatty matters and water through the tubes surrounded by fire, by which means the decomposition is rapidly and continuously carried on. I must not, however, conclude this part of my lecture without drawing your attention to these beautiful specimens illustrating the manufacture of Messrs. Price & Co., kindly lent to me by Mr. G. F. Wilson.

Spermaceti.—This valuable substance is found in large quantities in the bony receptacles of the head of the white whale of the South Seas, and as it is there mixed with a fluid substance called sperm oil, these are separated by means of filtration. The solid mass which is thereby left in the linen bags is first pressed cold, and then between heated plates (hot-pressed). It is then physicked, or heated in a boiler with a solution of caustic potash of specific gravity 1·45, which dissolves a small amount of oily matter, still adhering to the spermaceti, and this after being well washed is run into moulds to cool. The manufacture of spermaceti candles requires great care and practical experience. The only fact I shall mention is, that about 3 per cent. of wax is added to spermaceti to prevent the mass being too crystalline or brittle. M. Chevreul, who chemically examined pure spermaceti, or cetine, at the beginning of this century, succeeded in unfolding it into an acid, which he called ethalic acid, very similar to palmitic, and into a neutral substance called ethal, the composition of which, he prognosticated, would be found to contain pure alcohol. This, I am pleased to say, has proved to be the case; for its composition may be considered as represented by

$$C_{32}H_{33}O_3+HO.$$

Mr. Heintz has recently published a very elaborate paper on the composition of this substance, and states that spermaceti contains the following components:

		Ethal or oxide of cetyle.
Stearophanate, .	$C_{36}H_{35}O_3$	$C_{32}H_{33}O_3$
Margarate, . .	$C_{34}H_{33}O_3$	"
Palmitate, . .	$C_{32}H_{31}O_3$	"
Cetate, . .	$C_{30}H_{29}O_3$	"
Myristate, . .	$C_{28}H_{27}O_3$	"
Create, . .	$C_{26}H_{25}O_3$	"

It appears to me that several of these products do not exist ready formed in spermaceti, but are the results of chemical reactions.

Beeswax.—I have already had the pleasure, at the commencement of this lecture, of drawing your attention to the fact that bees either gather wax from the flowers on which they alight, or are capable of producing it direct from saccharine matters. The wax as it is obtained

from the honeycomb being colored, it is necessary to bleach it for most of the applications which wax receives. The old process (still followed in many parts of Europe) consists in melting wax in water, and allowing it to run into a second vessel, so as to separate it as completely as possible from its impurities. When cooled to nearly its melting point, it is allowed to fall on rollers which revolve in cold water, by which means thin ribbons of wax are obtained, which are then placed on meadows to bleach under the influence of the atmosphere. The above operations are repeated until the wax is perfectly bleached. This plan is so tedious and expensive that several chemical processes have been proposed. M. Casseraud's is, to pass steam through the melted mass, which is, at the same time, subjected to the influence of sunlight. Mr. Solly's is, to treat the melted wax by a mixture of nitrate of soda and sulphuric acid, when the nitric acid liberated oxidizes and destroys the coloring matters of the wax. Pure wax melts at 149°, and when treated with alcohol is found to be composed of

Cerine or cerotic acid, . .	$C_{54}H_{53}O_3HO$	65
Myricine, . .	$C_{92}H_{92}O_4$	30
Ceroleine, . .	. .	5
		100

Sir Benjamin Brodie, who examined most minutely the chemical composition of a great variety of waxes, considers that the substance called by chemists cerine is really cerotic acid, and that mycerine is a compound of palmitic acid and melissine. The lecturer here illustrated and explained the various adulterations of wax, giving the means of detecting them. The adulterations were common owing to its value.

Chinese wax is a compact substance, imported from China, and said to be secreted by an insect called *Coccus Pela sinensis.* This wax, which is harder and more brittle than beeswax, melts at 181, and has yielded in the hand of the above eminent chemist cerotic acid and cerotine, or oxide of cerotyle

(To be continued.)

On the Supposed Nature of Air prior to the Discovery of Oxygen.

By George F. Rodwell, F.C.S.

From the London Chemical News, No. 290.

Continued from page 200.

XII. *Rise of Scientific Societies.*—In the preceding paper we have considered the labors of the Accademia del Cimento in connexion with the subject under discussion. We have now to speak of two institutions which, unlike the Italian Academy, have endured to our time, and have year by year extended their influence on the progress of the Baconian philosophy, until they have become the very centres from which its greatest results emanate—the Royal Society and the Academie des Sciences.

A few years after the death of Bacon, some of the more ardent of

the followers of the "new philosophy" agreed to meet weekly at each other's rooms for the trial of experiments, and for the discussion of subjects connected with experimental science; when the number of members of this infant society had somewhat increased, the meetings were held at the "Bull's Head," in Cheapside, and subsequently at Gresham College, but the latter was converted into a garrison during the Commonwealth, and the meetings were discontinued till 1660, when they were resumed at the College. The Society now received large accessions to its numbers, a journal book was commenced, and rules were drawn up relative to the election of officers and the admission of fellows. On December 5, 1660, it was notified to the members, that Charles II. had received information of the establishment of the Society, and that he had approved of its design, and desired to promote its welfare. In 1662 a charter was granted to the Society, rendering it a corporate body, under the title of "the Royal Society for improving natural knowledge." "*Nullius in Verba*" was chosen as the motto of the Society, and it may fitly be taken as the motto of the Baconian philosophy.

We have previously mentioned that Baptista Porta called one of his scientific works "Natural Magic," to distinguish it from contemporary writings on similar subjects, in which unusual physical effects were attributed to supernatural causes; now it was for a like reason that the Royal Society was defined as an institution "for improving *natural* knowledge." It was founded at a time when much of the superstition of the Middle Ages still prevailed, when it was no uncommon thing to burn those suspected of witchcraft, to cast horoscopes, to seek for hidden treasure with divining rods, to practise many of the old Chaldæan mysteries. The Society was to ignore all this; it was to look to natural causes for the explanation of new or hitherto unexplained phenomena, and to prove the fallacy of those superstitions which Bacon had spoken of as "mere levities that have little in them of certainty and solidity, and may be plainly confuted by physical reasons."* The influence of the Society in this direction was considerable, for we find a manifest lessening of superstition soon after its establishment.

Among the early fellows of the Society were Ward, Wallis, Sir Robert Moray, Bishop Wilkins, and Robert Boyle; the latter labored most indefatigably for the good of the Society; indeed, it may be considered as in a great measure due to his influence, that it obtained a permanent footing. At the early meetings of the Society, the subjects discussed related chiefly to the Copernican theory, the spots of the sun, the Torricellian experiment, and the improvement of telescopes; experiments were made to determine the length of time that a candle continued to burn in a cubic foot of (*a*) common air, (*b*) rarefied air, and (*c*) condensed air; thin glass bubbles filled with air at the ordinary pressure were caused to swim in condensed air, and experiments were made on the increase of weight of some metals during calcination. It could not, however, be expected that the super-

* "Advancement of Learning," book 3, chap. 4.

stitious element so prevalent at this period, would be entirely excluded from the discussions of the Society, especially when it numbered among its fellows such men as Sir Kenelm Digby and Sir Gilbert Talbot; nor was it at once excluded. Thus on June 26, 1661, we read that "Dr. Ent, Dr. Clarke, Dr. Goddard, and Dr. Whistler, were appointed curators of the proposition made by Sir G. Talbot to torment a man presently with the sympatheticall powder." July 31: Mr. Croune exhibited before the Society a jar full of the powder of the bodies of vipers, and another full of the powder of the hearts and livers of vipers. On September 4, Sir Kenelm Digby read an account of "a petrified city and its inhabitants." Even the divining rods were thought worthy of examination by these early philosophers. July 10, we read: "The fresh hazell sticks were produced, wherewith the divining experiment was tried, and found faulty."

At this period but little was known of foreign countries, and travelers were wont to grossly exaggerate the wonders they had seen; and more than this, often to state the most glaring impossibilities—for instance, that diamonds grew in the mines in which they were found; that there existed a river of pure balsam; that in certain countries the natives whistled so loud as to be heard at a distance of five miles, and such like absurdities; we remember to have seen in the "Mundus Subterraneus" of Athanasius Kircher (a man who had traveled much) a detailed account, accompanied by an engraving, of an encounter with a dragon. At an early period of its existence, the Royal Society sent a number of questions to residents in foreign countries, with a view to ascertaining to what extent the assertions of travelers might be relied upon, and further for the purposes of scientific inquiry. In 1661 a number of questions were sent to a resident in Teneriffe; they were proposed by Lord Brouncker and Robert Boyle, and many of them were obviously for the purpose of ascertaining the difference between the air on the summit of a lofty mountain and that at its base. The recipient of the letter was desired, among other things, to try the Torricellian experiment at the top and bottom of the mountain, and to note the exact difference in the height of the mercury column; to carry up partially inflated bladders, and to observe to what extent they altered in bulk at various elevations; to weigh a bottle of air at the top and bottom of the mountain; to observe whether birds loaded in such a way that they can just fly at the bottom of the mountain, are able to fly at its summit; to ascertain if there is any moisture in the air at the summit of the mountain, and if a siphon will act there readily.

The first number of the Philosophical *Transactions* was published on March 1, 1665, and from that date to the present, the publication has been continued uninterruptedly. The early volumes contain a very miscellaneous collection of subject-matter; scientific articles were by no means alone admitted—sometimes we find two of the most diverse subjects treated of in the same communication; thus in the number of December, 1667, there is an "Extract of a letter written by Mr. Sam. Colepress to the Publisher, containing an account of some

Magnetical Experiments; and also of an excellent liquor made of Cyder-apples and Mulberries." Astronomical papers occur rather frequently; medical papers less so; articles on pure physics are by no means common; the reviews of recently published books are of great interest and of frequent occurrence. We will briefly consider the various papers of importance connected with our subject which occur in the Philosophical *Transactions.*

1665. No paper relative to the air.

1666. Under the title of "*A New Statical Baroscope,*" Boyle describes an apparatus for showing changes in the weight of the air, which he considers preferable in many respects to a mercurial barometer. At one extremity of the beam of a balance capable of turning with $\frac{1}{30}$th of a grain, he suspended a sealed glass sphere full of air, about the size of a large orange; it was exactly counterpoised by a lead weight placed on the opposite extremity of the beam; minute movements of the beam were made apparent by an index which pointed to an accurately divided arc; the position of the sphere of course varied with changes in the density of the air, an alteration in which, represented by a rise or fall of one-eighth of an inch in the mercurial barometer, was clearly indicated by the statical baroscope.—Dr. Beal gives a number of barometrical observations, and states that he never found the mercury column higher than $30\frac{1}{4}$ inches, nor the extreme change to exceed $2\frac{7}{8}$ths inch. Dr. Wallis, during a great number of observations, did not observe the mercury higher than 30 inches, or lower than 28; he found it rise in foggy and sunshiny weather, and fall in wet and windy weather. Boyle, in giving directions as to how barometers should be observed, urges the necessity of ascertaining the exact elevation above the level of the sea of two localities, in which separate barometical observations intended for after comparison are being made—a point of great importance, which up to that time had been overlooked. In detailing the "General Heads for the Natural History of a Country," Boyle writes as follows: "Concerning the air, may be observed its temperature, as to the first four qualities and the measures of them; its weight, clearness, refractive power; its subtilty or grossness; its abounding with or wanting salts; its variations according to the season of the year, and the times of the day; what durations the several kinds of weather usually have, what meteors it mostly produces, and in what order they are generated, &c."

1667. Some experiments are mentioned by Dr. Beal relative to the growing of seeds in vacuo. Lettuce seed was planted in earth, part of which was placed in the open air, and part in vacuo; in eight days the seed which was planted in the open air had produced plants one and a half inch high, while that in vacuo had not sprouted; on admitting air to the receiver, the included seed produced plants from two to three inches high in a week's time. In a short notice of "*An Experiment of Sigr. Fracassati upon Blood Grown Cold,*" we find mention of an important fact hitherto unobserved, or at least unrecorded. The dark color of venous blood had for a long period been believed to be due to an admixture of the "melancholy humor," (one of the four

supposed constituents of blood.) Fracassati observed, however, that when dark colored blood was exposed to the air, its upper layer became bright red, while the blood beneath remained dark-colored; from whence he infers that the dark color of blood is not due to the "melancholy humor," but to the want of an admixture of air, since the presence of air at once converts it into red blood.

1668. In the *Transactions* for this year we have an interesting paper by Boyle, entitled "*New experiments concerning the relation between Light and Air in shining wood and fish,*" in which we find, among others, the following experiments: A piece of luminous rotten wood was placed under the air pump receiver; on exhausting it ceased to emit light, but when air was admitted the luminosity returned. In order to see if the light could be perfectly distinguished like that of a red-hot coal placed in a vacuum, pieces of luminous wood and fish were left in an exhausted receiver for from twenty-four to forty-eight hours. On admitting air the bodies immediately regained their luminosity. A piece of luminous wood was placed in a vessel into which air was compressed, but the wood did not shine brighter than before. A piece of luminous fish was placed in a bottle of water, which was included within a receiver, and the air exhausted, but no effect was produced. In order to ascertain whether "the cold fire" of shining wood could be maintained by a very small quantity of air, a piece of wood was hermetically sealed in a glass tube; it retained its luminosity perfectly for a length of time.

1669. No paper relative to the air.

1670. Boyle contributes an interesting paper entitled "*New pneumatical experiments about respiration.*" We have previously mentioned Boyle's experiments on respiration which he described in the first "Physico-mechanical experiments touching the air." In this paper we have a continuation and enlargement of his former experiments; those here described were principally made in 1662 and 1663. As ducks are able to remain for an appreciable time under water, Boyle conceived that they would form good subjects for experiment. Accordingly he enclosed one in the air-pump receiver and exhausted, whereupon the duck was brought to the point of death in a few minutes. A viper was alive at the end of two and a half hours, during which it had been kept in an exhausted receiver; a second was enclosed in a very small receiver, which was well exhausted; at the end of an hour and a half it was to all appearances dead, but on admitting air twenty-three hours afterwards, it proved to be alive. A large frog placed in a receiver was observed to swell out considerably when exhaustion was commenced; in a short time it appeared to be dead; at the end of three hours air was admitted to the receiver, and the inflated frog immediately shrank up to a very small size, still to all appearance dead; nevertheless, on being placed over night on grass in the open air, it was found to be alive and well the next morning. In order to ascertain whether animals "that had been lately accustomed to live without any or without a full respiration would not be more difficultly or slowly killed by the want of air, than others which had

been used to a free respiration," Boyle placed a kitten (born the previous day) in a small receiver and exhausted. At the end of six minutes it appeared perfectly dead, but on removal to the open air it recovered after a while; a second kitten which was left in vacuo for seven minutes did not recover when air was admitted. An oyster was kept in vacuo for twenty-four hours, and remained alive; a craw-fish also lived in vacuo; a leech which was kept in an exhausted receiver was found to be alive and well at the end of five days. The heart of an eel just taken out was placed on a tin plate in an exhausted receiver; it continued to beat for an hour. A gudgeon remained alive for some time in vacuo. From the numberless bubbles of air which ascend from water placed in vacuo, Boyle puts it as a query "whether in common water there may not be concealed air enough to be of use to such cold animals as fishes; and whether it may be separable from the water that strains through their gills." In order to see if the volume of air is altered by animals breathing in it until it is incapable of supporting life, birds and mice were placed in tubes together with a mercury gauge, the tubes were then hermetically sealed, and put aside until the animals and birds were suffocated; the gauge indicated no change in the volume of air within the tubes. As it would be of service in our comprehension of the minuteness of a particle of air, if it could be proved that very minute insects breathe, Boyle placed a number of mites in a small receiver and exhausted; on examining them with a lens, they were observed in a short time to become perfectly motionless, and to continue so, but on the admission of the air they manifested considerable liveliness, whence he considers that it may be taken as proved that they breathe.

1671. The only paper of interest in connexion with our subject in this year's *Transactions* is a short one on "*The Compression of Air by Water*," in which the following experiment is detailed: A glass bottle of a quart capacity was fitted with a valve opening inwards; it was sunk in the sea, mouth downwards, to a depth of thirty-three feet; on drawing it up, it was found to be half full of water, proving that the weight of a column of water of thirty-three feet high had compressed the air in the bottle to half its volume, as might have been predicted from the previous experiments of Boyle and Hooke on the compression of air by a column of mercury.

1672. When a tube five or six feet long, closed at one end, is filled with mercury perfectly free from air, and then inverted into mercury, after the manner of making the Torricellian experiment, the mercury in the tube will freqently be found to remain suspended at a much greater elevation than that at which the pressure of the atmosphere would cause it to remain; but if the tube be shaken, or if a slight blow be given to it, the column at once falls to its usual height of 30 inches above the stagnant mercury. In order to account for this, Huygens proposed a most unphilosophical theory, (contained in a letter to the *Journal des Savans*, and reprinted in this year's *Phil. Trans.*,) which affirmed that, in addition to the pressure of the air, there is a second pressure of a more subtle matter than air, which is able to

penetrate glass, water, and mercury, and that it is due to this additional pressure that the mercury column under the above circumstances remains suspended above 29 inches. Although this hypothetical matter could penetrate glass, Huygens conceived that so long as the mercury was absolutely in contact with the end of the glass tube, so that there was no free space in the tube, it could not be readily pressed upon, but on shaking or jarring the tube, the mercury was separated from its close contact therewith, and the subtle matter immediately rushed in and caused the descent of the mercury. He conceived further that the presence of this additional pressure was proved by two experiments: the one, that a siphon will act *in vacuo;* the other, that two perfectly plane plates placed in contact will not separate *in vacuo* any more than in air, although a weight may be attached to them.

The Académie des Sciences was founded 1666, mainly by the exertions of Colbert, Carcavy, Auzout, Huygens, and Roberval. During the century it published ten volumes of proceedings, known as the "Anciens Memoires de l'Académie." In 1699 the Academy underwent an entire reorganization, and from that time to the present the memoirs have appeared more frequently.

There are only two papers of interest in connexion with our subject which appeared before 1673, (to which date we have taken our notices of the *Philosophical Transactions.*) The first is "On the Augmentation of Weight of Certain Matters during Calcination." In this the author, M. du Clos, gives the following explanation of the cause of the increase of weight observed. He conceives, "Que l'air qui coule incessamment vers les endroits, où il y a du feu, laisse surces matieres embrasées pleine de souffres terrestre, des particules sulphurées plus volatiles, qui s'unissent avec eux, s'y fixent, et forment ces filamens dont nouse avons parlé, qui sont apparemment toute augmentation du poids." The other paper details some vacuum experiments, almost all of which had been previously made. No mention is made of Boyle's air pump, and Otto Guericke's form of the instrument was apparently employed. In order to ascertain whether heat passed as readily through a vacuous space as through air, some butter was placed in a receiver, and a hot iron held as near to it as practicable outside the receiver. The butter did not melt so readily when the receiver was exhausted as when it was full of air, probably, according to the author, (whose name is not mentioned,) because air in virtue of the grossness (grossièreté) which it possesses, is more capable of conveying heat from the hot side of the receiver to the butter than the very thin and subtle matter which remains in the receiver after the air has been pumped out.

(To be Continued.)

On the Decay of Materials in Tropical Climates, and the Methods employed for arresting and preventing it. By G. O. Mann.

From the Civil Engineer and Architect's Journal, December, 1864.

The facts and experience recorded in this paper had reference particularly to the empire of Brazil, the author being the resident engineer and

locomotive superintendent of the Recife and San Francisco Railway Company. It was stated that the temperature varied less probably than in any other quarter of the globe; but the seasons, which it was believed influenced the decay of materials to a greater extent than the temperature were not so regular. Thus, the rainfall ranged from 60 inches to 120 inches per annum, and this did not occur at any particular period, though a certain peculiarity in the climate, excessive heat combined with much moisture, was noticeable more or less throughout the year.

It had been found on the Pernambuco railway, that the half-round intermediate sleepers, of timber from the north of Europe, creosoted, were in a better state of preservation than the square sawn joint sleepers of the same material; still, after seven years' trial, it was evident that creosote, when properly applied to suitable descriptions of timber, would prevent decay. In white-sand ballast, since the opening of the first section of the line in 1858, the half-round sleepers had not suffered a depreciation of more than one per cent., while the square sawn sleepers had experienced a depreciation of not less than fifty per cent. On the other sections of the line, sleepers of native timber were employed with unsatisfactory results; this was due, it was asserted, to the timber having been cut at unfavorable seasons, and to the sleepers having been laid in a green state, owing to the rapid progress of the works not allowing time for them to become dry. The author, after nearly seven years' experience, was confident, however, that properly selected timber of the country would be found more durable than any description of wooden sleeper yet imported. It was advisable, in order to prevent decay, to cut the timber during the dry season, to select large and full-grown trees, to remove the whole of the bark and sapwood, leaving the heart of the timber only, and not to expose the sleepers in the sun when fresh cut, but to stack them in open piles under cover, through and about which the air could freely circulate for a few months. The cost of such sleepers delivered at the stations on the Pernambuco railway was at present 2*s.* 7*d.* each, the scantling being 10 inches by 5 inches by 9 feet. Imported creosoted sleepers had invariably cost double that amount.

Respecting timber in general, it was remarked that good timber for building purposes abounded in Brazil, in the greatest variety. Many kinds were impervious to the white ant, which insect generally selected the more porous descriptions, and particularly those in contact with the earth. In dry places, and with a free circulation of air, the white ant did not, in preference, select timber thus situated for its ravages; and it was found that the roofs of buildings, of good and well seasoned native timber, resisted for an indefinite period, both the climate and the white ant. Latterly it had been the practice to "pay" over, with coal tar, the ends of all timber built into the gables of buildings, or in any other position in which it was buried, or excluded from the air, and so far apparantly with beneficial results. Two specimens were exhibited of the piles of the old Recife wooden bridge, which had been constructed in 1614, in proof of the durability of the native timber; and it was asserted that, with proper precautions, no foreign

timber would be found able to compete in the tropics with that of native growth.

The only examples of iron bridges in the province of Pernambuco, except that of St. Isabel, completed in 1863, were those belonging to the railway. The result of a careful examination of four of these structures, after they had been erected six years, was to show that the cast iron pipe piles, forming the piers, were likely to remain good for a considerable period; and that the upper structures of wrought iron would also last well with ordinary attention. The only parts apparently affected were the wrought iron bracings, and the bolts and nuts below high-water mark. With regard to the preservation of iron bridges, and of iron work in general, for the tropics, care should be taken to insure the iron being perfectly dry before the paint or any other composition was laid on. Coal tar had been found to afford a most efficient protection. It was advisable that all small pieces should, before being shipped, be heated to a low temperature, and then brushed with, and dipped in, tar; the larger parts should be well cleansed, and the tar laid on while hot. Where tar was objectionable, linseed oil might be applied in the same way, and over this there should be a thin coating of zinc paint.

With regard to building materials, stone, wherever it could be obtained at a reasonable price, should be preferred for the abutments and piers of bridges. Stone imported from Portugal, for facing the churches, and in a few old Dutch works of the seventeenth century, had been found to be very durable. Great caution was necessary in the selection of bricks, as those made near the sea-board, with brackish water, were very susceptible to the weather, and mouldered away rapidly when exposed. As it was all but impossible to obtain thoroughly well-burnt bricks in large quantities, all brickwork near to the sea-coast required to be protected with plaster from the first, and in the interior this was ultimately necessary, or else a thick coating of lime whitewash might be given from time to time. Tiles made of similar, though where obtainable of better, clay, when well burnt, were scarcely affected by the weather, either on the sea-board or in the interior. Rafters were selected from young trees, and if of the proper quality of timber, had considerable duration. Laths were in nearly all cases made from the sap wood of "imberiba," perhaps the hardest and most durable description of timber in Brazil.

The permanent way keys, used for renewals since the opening of the Pernambuco railway in 1858, had been cut from native timber, of a remarkably close nature, which did not shrink, as the imported keys were found to do. The rails oxidized when left near to the sea-coast, so that it was desirable to remove them to the places where they were to be used as soon as possible. The motion of the trains appeared to prevent rust from forming on the rails, but owing to the high temperature they were always at during the day, and to the constant passage of the trains, there was tendency in them to become flattened. About 10 miles of the line had been laid with Greaves' "pot" sleepers, as to the durability of which in the tropics there could be no question,

but they were found to make a rigid road, even in fine sand ballast. This portion of the line had been improved, by introducing fish plates, and suspending the joints. The railway carriages were made with a strong wrought iron under-frame; the body and the inside lining were of teak; and the outside panels were of papier maché. These carriages were in excellent preservation, after six years' work and exposure to the sun and rain.

In the appendix a list was given of those Brazilian timbers now being used for sleepers on the Pernambuco railway, and of such as were suitable for general purposes in permanent structures, as well as a table of the specific gravities of the kinds adapted for ship building.

On the Decay of Materials in Tropical Climates.

By William J. W. Heath.

From the London Civil Engineer and Architect's Journal, January, 1865.

During a residence in Ceylon, extending over a period of seven years, while engaged on the railway, Mr. Heath's attention had been directed to those materials which were most used in the construction of permanent buildings. The habitations of the lower class of natives were formed of a rude framework of stout bamboos, the sides and roofs consisting of reeds, closed in with the interwoven leaves of the cocoanut palm, the latter being washed over with the slimy juice of a native fruit, which, when dry, resembled copal varnish. In the huts built of "wattle and dab," the framework was made of roughly squared jungle trees, the space between being filled, and both the inside and the outside of the hut being covered with clay and sand well kneaded, afterwards plastered over with earth thrown up by the white ants, mixed with a powerful binding substance produced by the ants. Superior houses were built of "cabook," a soft kind of rock, found at a few feet below the surface. This material had the appearance of a coarse sponge, the interstices being filled with clay. Before being used the blocks should be exposed to the rain, to allow some of the clay to be washed out. Cabook required to be protected from the weather, but if covered with a thin coating of lime plaster, it would last for years. Hard kinds of stone were not much used owing to the expense of working them; and rubble masonry was not approved, as there was difficulty in obtaining even bed sand good bond. Bricks as a rule were so badly burnt, and the clay was so badly pugged, that brickwork in exposed situations and unprotected would perish very rapidly. It was advisable that it should in all cases be well plastered with lime mortar. Two or three coats of boiled linseed oil would preserve brickwork without hiding it, but the expense prevented its general use. Coal tar was an excellent preservative, but on account of its unsightly appearance it could not be often employed. Lime was generally made by calcining white coral. When taken from the kiln it was in a fine white powder, fit for immediate use, after being mixed with twice its

own bulk of sand and water. It set so rapidly that, in the Public Works Department it was the practice to keep the lime under water for two days before using it. This had the effect of making it longer in setting, but it was more easily worked, and eventually made better work, equal, in fact, to the best blue lias lime. Well seasoned timber, with free ventilation, would endure for many years, if the white ants were kept away, without any precautions being taken to preserve it. In exposed situations, and where subject to the attacks of the white ant, Stockholm tar was the best preservative; while creosoted timber was free from their ravages. In sea water, and even in fresh water lakes and canals, timber was speedily attacked by worms, notwithstanding that it might be painted, oiled, or tarred.

Iron exposed to the influence of varying weather speedily oxidized, but oil, applied hot, was a good preventive. Coal tar was, however, the best covering applied either cold or hot, or before or after oxidation had commenced. Ordinary galvanized sheet iron did not last many years, unless protected with good red lead paint frequently renewed; but zinc would last for many years with little or no decay.

In the course of the discussion it was stated that on the Great Indian Peninsula Railway, Baltic sleepers both creosoted and kyanized, and native jungle wood sleepers had been used; but after thirteen years' experience, those which had failed were being replaced by teak and iron sleepers. The native woods were so hard and close grained that they could not be impregnated with any preservative substance. The keys were a source of great trouble in warm and variable climates. Those of wood had not been found efficient in India, and endeavors were now being made to devise a substitute. Iron work of all kinds should be thoroughly cleansed, dried by heat, and then dipped in hot linseed oil before being exported from this country.

It was contended that it was impossible to predicate what timber would sustain, for while yellow pine had been known to last sound as railway sleepers for twenty-five years, in other cases it had decayed in five or six years. This frequently happened also with hard tropical woods, without there being any apparently assignable cause for this difference in the rate of decay. Hence, in the tropics, iron was nearly the only material that could be employed especially for sleepers with anything like certainty as to the results. No doubt iron made a rigid permanent way unsuitable for the high speeds common in this country, although possibly this might be partially obviated by a more perfect manner of securing the rails on the sleepers; but in the tropical climates the use of iron was almost a necessity, and there a speed of from 25 to 30 miles per hour was a maximum. Greaves' cast iron bowl sleepers had been laid for eighteen years on the Egyptian railway, and made a good and substantial road. The objection that they were liable to break, particularly along the centre line, might be met by making them stronger; and it was remarked that on the Dom Pedro Segundo Railway, Rio Janeiro, the bowl sleepers had been in use for eleven years, and only one sleeper per mile had required to be renewed.

On the East Indian line, of more than 100 miles in length, the sleepers were principally of sâl timber, but there were others of creosoted fir and of iron. Although there were many different kinds of suitable native woods, there was difficulty in obtaining large quantities of any other than sâl, which, when cut out of large timber and well seasoned, was very durable. Recently in opening a part of the line near Calcutta, sâl sleepers had been found in a good state of preservation after having been laid twelve years. In other parts of the line, creosoted sleepers were in a serviceable condition after being in use ten years. Teak was perhaps the best of all Indian woods, but the cost precluded its use for sleepers, as it would amount to 15*s.* per sleeper. Flat iron sleepers had been unsuccessful, but cast iron bowl sleepers seemed to promise better results, although at present they had not been sufficiently long in use to enable a definite opinion to be pronounced. The breakage so far had been serious, amounting to about 20 per cent., but this might be obviated in future by making them stronger, as had been suggested. The use of iron was desirable on account of the difficulty of obtaining large supplies of timber sleepers, and the uncertainty as to their quality.

Although the decay of materials in Ceylon was unquestionably influenced by the alternating effects of heat and moisture, yet it was believed to be principally due to the use of inferior materials. In the upper districts of India, there were brick and stone buildings of great antiquity, in fact anterior to historic periods. Sâl timber was hard, durable, and abundant in the central forests, and along the base of the Himalayas, and had been generally employed by the Public Works Department; but owing to the great demand of late years, it was now hardly possible to obtain it well seasoned. Teak was also becoming scarce; that which grew in the province of Burmah was of large size and very useful for shipbuilding; while when cultivated in a drier range and upon rocky ground it was as hard as ebony or iron wood, though of small scantling and of crooked form.

It was noticed as remarkable that the observations in one paper were repeated in the other, and that the means of preservation which had been suggested as applicable in Brazil, were likewise recommended for Ceylon. There were, however, some points of difference—especially as to the use of galvanized iron. The author of the first communication, speaking apparently from opinion rather than from experience, advised its use, while the author of the second, on the contrary, thought that galvanizing alone, without painting or tarring, was not adequate to protect iron in such climates. As corroborative of the remark, that the loss of weight in iron from oxidation was less in Ceylon than in England, in an equal period of time, it was mentioned that out of a quantity of rails, which had been manufactured at the same time and at the same place, some were lying for many months unused in Ceylon, and others in South Wales, when the loss of weight by rust was found to be largely in excess at the latter place. Where there was great heat, combined with excessive moisture, it was imagined that the effect upon materials, particularly timber, could not be otherwise

than serious. While, in the first instance, it might be prudent to import timber artificially prepared, owing to the absence of available data as to the character of the native materials, yet it was believed, as the qualities of the different kinds of native woods became better known, as well as the proper time to fell them, and to prepare them by shed-drying or otherwise, and as a more ready access was obtained to the forests, native woods might ultimately be used with advantage and economy. In fact, a specimen of native Brazilian wood had been exhibited, which had endured for two hundred and fifty years. The alleged excessive wear of the rails and tires in Pernambuco must be explained upon other grounds than the heat. Perhaps the fact that the rails were not "fished" until after a portion of the line had been opened for traffic, that there were considerable curves on the line, and that the road was not laid in the perfect manner which was possible in this country, added to the great atmospheric alternations, might be sufficient to account for it.

It was remarked that in using unprepared wood, no doubt it was desirable to select that part which is hard, as the pores being filled with ligneous matter, such timber did not so freely absorb moisture. But for creosoting purposes the reverse was the case, for it was impossible to make heart-wood absorb 10 lbs. of oil per cubic foot, as was sometimes required. The great value of creosoting was that it enabled young wood to be used, as then, the pores being filled with a bituminous asphaltic mastic, the wood so treated was perfectly water proof, and harder than heart-wood. The reason why the half round sleepers on the Pernambuco line were more durable than those of square form, was believed to be due to all the young wood being retained in the former. Recent experiments in the harbor of Ostend showed that wood prepared with corrosive sublimate, or with sulphate of zinc or copper, was only partially protected against the worm, but when creosoted the worm would not touch it. It was advisable that piles in sea water should not be squared, but used round, with as much young wood as possible.

Respecting the ravages of the white ant, there were many old structures in Brazil not so affected; and as regarded railway sleepers, the frequent shaking and vibration would, it was considered, render them tolerably safe. In that country, porous and open-grained timber seemed most subject to these attacks; but in Australia the hardest kinds were first attacked. This was especially the case with iron bark timber, the density of which was so great as to cause it to sink in water, and in tenacity and resistance to strain it approached rough cast iron. White ants were effectually destroyed by oil of creosote, and anything of a bitter taste injected into the fibre, or even a small quantity of turpentine, would prevent their attacks. In some parts of India white ants were very destructive, and 10 per cent. of some stacks of sleepers had been decayed at the heart, in from six to eight months. The black ants of the West Indies were also more destructive in hard than in soft wood. Some descriptions of wood there were, neither affected by the teredo navalis, nor by the black ant, and when used for piles had never been known to decay.

With regard to stone it had been found that the application of linseed oil not only acted as a preservative, but it rendered soft stone in the course of a short time very hard. In Jamaica, the bricks were well made and of good materials; and some buildings there had stood from time immemorial without exhibiting any signs of decay. Mortar, both there and at the Cape, was made of shell lime, and even when mixed with sea sand it was hard and durable. In India, the addition to the lime of 5 per cent. of jaggery, a coarse native sugar, caused the mortar to set well and to be very durable. At the Cape the bricks were not good, and owing to the exudation of phosphate of soda after the work was finished, it was advisable to plaster all brickwork. In India the telegraph posts were, to a large extent, of stone obtained from Agra, and the rapid decay of timber when used for that purpose had greatly retarded telegraphic extension in that country. The difficulty was now being met by making the lower parts of the posts of iron, into which wooden posts were inserted.

Respecting the statements that the only examples of iron bridges in the province of Pernambuco were those belonging to the railway, and that of St. Isabel, completed in 1863, it was remarked that, about twenty years ago, a French engineer, M. Vauthier, when engineer-in-chief to the Province, designed and erected a suspension bridge on one of the main roads, about nine miles from the city, across the river Capibaribe, at the village of Caxangà. The roadway, which was 100 feet long by 20 feet wide, was suspended from a pair of iron wire ropes on each side of the bridge by vertical rods of wrought iron, the attachment of the rods to the ropes being by means of strong wrought iron plates, embracing both ropes. Each rope was in four separate pieces, and consisted of a mass of wire simply laid together and bound at intervals. The rocking standards were of cast iron in three pieces, and the platform was of wood. All the work was executed in the country, including the casting of the standards, but the wire was purchased in England. The ropes as well as the cast and wrought iron work were still sound. The cost had amounted to between £5000 and £6000.

Electricity.—Measurement of Inductive Resistances.

From the London Mechanics' Magazine, February, 1865.

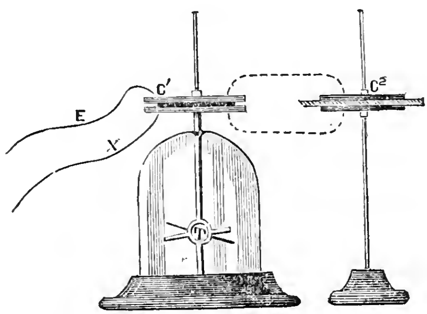
In a recent article, we noticed a system of measuring inductive resistances which will probably be found applicable with advantage whenever considerable lengths of manufactured cable are to be tested. We have now to describe a method which may be found particularly useful in testing specimen lengths of covered wire, even of a few inches, or samples taken from the bulk of materials considered to be adapted for the insulation of submarine wires; and which may consequently be of advantage to the manufacturer, and those generally who are engaged in perfecting the *materiel* of submarine telegraphy. The method in question is, if the results obtained be carefully worked out, susceptible of very great accuracy in what may be termed the quantitative

measurement of inductive resistance, but its practical value mainly resides in the fact that it affords a ready means of roughly determining the relative merits of samples of insulating materials in regard to their specific inductive resistance, and also, when necessary, in regard to their resistance to the passage of electricity. Such a method has, in fact, long been required by those engaged in the manufacture of submarine cables, or in investigations relative to their construction.

Since the specific inductive resistance of various materials would be proportionate to the quantity of electricity communicated from a given source to a number of wires, of equal length and diameter, respectively covered to an equal thickness with the materials in question, (the outer surface of the insulating materials being coated with tin-foil, or other conductive substance, and in connexion with earth,) it might be assumed that this property would be determined with sufficient accuracy for practical purposes by merely bringing each of the coated wires, successively, in contact with a Peltier or other electrometer charged to a given number of degrees, say 60 deg., and observing the diminution in the deflection produced in each case. Such, indeed, would be the fact if the conductive resistance of the materials might be considered as infinitely great; but, practically, a charge of the tension requisite to give comparable readings upon the electrometer (a tension, perhaps, equal to that of a battery of several thousands of cells,) would instantly, on contact being made with the wire, be almost wholly discharged from the instrument, the electricity flashing to earth through the substance of insulating material.

It is necessary, therefore, in order to render practicable so simple a mode of testing, that the tension necessary to furnish the indications should be—to use an almost absolete but expressive electrical term—*dissimulated* in great measure, whilst contact is made between the electrometer and the coated wire. This observation will probably suffice to render perfectly intelligible the *rationale* of the method now to be described. To the electrometer is fitted a condenser of an inductive resistance proportionate to the resistances to be measured—*i.e.*, a metal disk is screwed upon the upright stem of the instrument, and upon this disk is placed a second one, furnished with an insulating handle; the size of the disks and distance between them (maintained by means of a few drops of sealing wax upon either plate) being regulated according to the length of the sample insulated wires to be tested. If, now, the upper plate of the condenser be brought into contact with a wire connected to earth, whilst at the same time the lower plate is brought into contact with one pole of a properly insulated battery of 80 or 100 cells, (the other pole of which should be to earth,) the apparatus will receive an electrical charge of considerable *quantity*, but of a tension sufficient only to produce a very slight deflection of the electrometer needle. When, however, we remove the upper plate of the condenser by means of its insulating handle, the needle will be very strongly deflected, the original deflection of (say) 2 or 3° becoming 30 or 40°, according to the size of the condenser and the disance between the plates.

If, upon charging the electrometer by means of the condenser several times in succession, we obtain a constant deflection when the upper plate of the condenser is removed, we may then be tolerably certain that the whole of the apparatus is in proper condition, and we may in that case proceed to the testing of samples of insulating materials. These samples may either be in the form of similar short lengths of wire coated to the same thickness in each case with the respective materials, or in the more convenient form of small portions of the material in bulk, rolled or cast into sheets of *equal thickness*. In the latter case the sheets, which need not be cut to the same size, are to be inserted between the two plates of a second small condenser, one of which plates, insulated from earth, represents the wire in a short length of cable; whilst the other, connected to earth, represents the conducting substance in contact with the external surface of the insulating material upon this wire.



It is evident that if, after having charged from the battery the lower plate of the condenser attached to the electrometer, and whilst the upper plate is still connected to earth, we bring the former into contact with the wire, or disk, insulated from earth by means of one of our samples of insulating material, a certain quantity of electricity will be abstracted from this charged plate. This quantity, under the conditions in which the experiment is performed, will be proportionate to the specific inductive capacity of the insulating material in question, which will, therefore, be approximatively indicated by the greater or less deflection of the galvanometer needle when the upper plate of the condenser is removed. Such is the simple principle upon which dependable quantitative results may directly be obtained upon this system of testing. To exemplify the process, we may instance some tests applied to four specimens of insulating materials, viz: of gutta percha, india rubber, Macintosh's compound of india rubber and paraffin, and pure paraffin. The deflection of the galvanometer needle upon charging the condenser was about 3°. When the upper plate of the condenser was removed, the deflection became 31·5°. This result was obtained five times consecutively.

Exp. 1. The condenser was again charged from the battery, and, before breaking the connexion of the upper plate with earth, the lower plate was brought into contact with the insulated plate of a second condenser, which, as previously described, enclosed a portion of a sheet of *gutta percha*, of the same thickness as the sheets of other materials to be tested. Upon raising the upper plate of the electrometer condenser, the indication obtained was 15°, *i. e.*, the loss of tension was in this case 16·5°.

Exp. 2. The electrometer condenser having been completely discharged, and subsequently again charged from the battery, the lower plate was brought into contact with the insulated plate of the second condenser, forming a Leyden arrangement with a sheet of para rubber; the upper plate of the electrometer condenser, and one plate of the second condenser being maintained in connexion with earth. Upon raising the upper plate of the electrometer condenser, the indication obtained was 19°, and the loss of tension was consequently in this case only 12·5°. As the tension varies directly as the quantity of electricity accumulated under the same conditions, it is evident that the quantity of electricity abstracted from the condenser was in this case less than in the previous experiment, and that the inductive resistance of the india rubber was consequently considerably higher than that of the gutta percha.

Exp. 3. The tension indicated upon the electrometer after contact with the second condenser, enclosing a sheet of Macintosh's paraffin compound, was 20°. The loss of tension was therefore in this case 11·5°.

Exp. 4. The same operation being repeated with a sheet of pure paraffin, the loss of tension was found to be only 8°; the electrometer indication being 23·5°. It thus was rendered evident that the inductive resistance of the paraffin was very considerably higher than that of the other materials tested, a result which, without any more accurate expression of the comparative resistances, was in itself of considerable practical importance.

In testing as above, the experimenter might, without liability to serious error in regard to the result in view, assume empirically: First, that the indications of the Peltier electroscope give the true measurement of the electrical tensions, and consequently of the quantity of electricity accumulated at any given time as a charge upon the instrument; and, second, that the specific inductive *capacities* of the samples of insulating material tested are proportionate to the loss of tension that occurs in each case after contact has been made between the two condensers as described. Upon this assumption, the specific inductive capacities would bear the following proportions to each other: Gutta percha = 16·5, india rubber = 12·5, india rubber and paraffin compound = 11·5, pure paraffin = 8, and the specific inductive *resistances* would be as these numbers inversely.

The theory, however, of the distribution and redistribution of a given quantity of electricity in two or more branches of an inductive circuit, when an alteration in the conditions of this circuit takes place after the source has been withdrawn,* is now very generally understood; and the electrician will have but little difficulty in obtaining an accurate quantitative expression of the specific inductive resistances of samples of insulating materials tested upon the above system, provided he can assume that the electrometrical indications (obtained by means of a Peltier instrument graduated to verified battery tensions, or of a Thomson's electrometer) are sufficiently near the truth. The electrical law ap-

* Vide F. C. Webb's "Electrical Accumulation and Conduction," chap. 5.

plicable to the case under consideration is stated by Mr. F. C. Webb, as follows: "The quantity generated at one pole of a source will divide itself on the surfaces which it charges in the inverse ratio to the inductive resistance separating those surfaces from the opposing surfaces, to which the other pole is connected." Thus, if we call Q the quantity of electricity accumulated upon the condenser No. 1 (that attached to the electrometer); Q' the quantity of electricity accumulated upon condenser No. 2 (that enclosing the sheet of insulating material); R = 1 the inductive resistance of condenser No. 1; and R' the inductive resistance of condenser No. 2, equal to the specific inductive resistance of the sample of insulating material tested:

$$\text{then, } Q' : Q :: R : R' \text{ and}$$

$$R' = \frac{Q\,R}{Q'};$$

$$\text{or, since } R = 1,\ R' = \frac{Q}{Q'}.$$

The theoretical deductions from the experiments above described, in which the specific inductive resistances of four different specimens of insulating materials were tested, would be as follows, assuming always the electrometrical indications to be sufficiently accurate: calling T and T' the tensions upon condenser No. 1 and condenser No. 2, respectively; upon charging condenser No. 1 from the battery, as previously described, and raising the upper plate,

$$T = 31{\cdot}5$$

$$Q = \frac{T}{R};$$

R being constant, Q = 31·5, and

$$R = \frac{T}{Q} = \frac{31{\cdot}5}{31{\cdot}5} = 1.$$

Exp. **1.** Determination of inductive resistance of gutta percha. When the upper plate of condenser No. 1 is raised, after connecting condenser No 2 as a branch inductive circuit, T = 15; Q = 15; R = 1; the electrical conditions in condenser No. 2 would be, in like manner: $T' = 15$; $Q' = 31{\cdot}5 - 15 = 16{\cdot}5$; and $R' = \frac{15}{16{\cdot}5} = 0{\cdot}909$. (Applying the well known equation for branch circuits, inductive or conductive, viz: $R = \frac{r\,r'}{r + r'}$; the total resistance of the combined circuits is $R = \frac{1 \times 0{\cdot}909}{1 + 0{\cdot}909} = 0{\cdot}47616$; and the total $Q = \frac{15}{0{\cdot}47616} = 31{\cdot}5$, remaining, of course, unaltered.)

Exp. 2. Specific inductive resistance of india rubber. Condenser No. 1: T = 19; Q = 19; R = 1. Condenser No 2: $T' = 19$; $Q' = 31{\cdot}5 - 19 = 12{\cdot}5$; and $R' = \frac{19}{12{\cdot}5} = 1{\cdot}520$.

Exp. 3. Specific inductive resistance of compound of india rubber

and paraffin. Condenser No. 1: $T = 20$; $Q = 20$; $R = 1$. Condenser No. 2: $T' = 20$; $Q' = 31{\cdot}5 - 20 = 11{\cdot}5$; and $R' = \frac{20}{11{\cdot}5} = 1{\cdot}739$.

Exp. 4. Specific inductive resistance of pure paraffin. Condenser No. 1: $T = 23{\cdot}5$; $Q = 23{\cdot}5$; $R = 1$. Condenser No. 2: $T' = 23{\cdot}5$; $Q' = 31{\cdot}5 - 23{\cdot}5 = 8$; and $R' = \frac{23{\cdot}5}{8} = 2{\cdot}9375$.

The specific inductive resistances of the four materials would therefore be as follows: Gutta percha 0·909, india rubber (pure para.) 1·520, compound of india rubber with paraffin (the specimen contained also some carbon in the form of lampblack) 1·739, pure paraffin 2·9375. It has been mentioned that the apparatus which is employed as above in the measurement of inductive resistances of specimens of insulating materials may also be applied to the determination of their conductive resistance. The mode in which the testing is in this case affected will be understood by the practical electrician, when it is stated that the pole of a battery is connected to one plate of what we have termed condenser No. 2, the other plate of this condenser being connected to the lower plate of the electrometer condenser, of which the upper plate is brought in contact with earth. At the end of a given time (a few minutes) the connexions are broken, and the last mentioned plate is removed. The electrometer indication will then indicate the amount of leakage which has taken place through the substance of the sample tested.

On a new Thermo-Element. By M. S. Marcus.

From the London Chemical News, No. 286.

The author has given the following accont of the properties and construction of his new thermo-element:

1. The electro-motive force of one of the new elements is $\frac{1}{25}$th of that of Bunsen's element, and its resistance is equal to 0·4 of a metre of normal wire.

2. Six such elements can decompose acidulated water.

3. A battery of 125 elements disengaged in a minute 25 cubic centimetres of detonating gas. The decomposition took place under unfavorable circumstances, for the internal resistance was far greater than that of the interposed voltameter.

4. A platinum wire half a millimetre in thickness introduced into the circuit of the same wire is melted.

5. Thirty elements produce an electro-magnet of 150 pounds lifting force.

6. The current is produced by heating one of the junctions of the elements and cooling the second by water of the ordinary temperatures.

To construct this battery it is necessary, on the one hand, to procure two electromotors suitable for a thermo-element, and, on the other, to have such an arrangement of the elements and of the means

for heating and cooling as will ensure as favorable a result as possible. The former constituted the physical, the latter the constructive part of the problem.

In solving the first part of the problem, it was the author's endeavor

a. To use such thermo-elements as are constructed of metals as far apart as possible in the thermo-electric series, and

b. Such as permit great differences of temperature without using ice, which is only practicable if the bars possess as high fusing points as possible.

c. The material of the bars must not be costly, and the bars themselves must be easily constructed.

d. The insulation used for the elements must be able to resist high temperatures, and must possess sufficient solidity and elasticity.

As neither the usual bismuth antimony couples, nor any combination of the other simple metals satisfy these conditions, M. Marcus availed himself of the circumstance that alloys in the thermo-electric pile do not stand between the metals of which they consist, and was thereby led to the following alloys, which completely satisfy the above requirements:

For the positive metal

10 parts of copper,
6 " zinc,
6 " nickel.

An addition of one part of cobalt increases the electro-motive force.

For the negative metal—

12 parts of antimony,
5 " zinc,
1 part of bismuth.

By repeated remelting the electro-motive force of the alloy is increased.

Or he used a combination of argentane (known as alpacca from the Triestinghofer Metal Manufactory) with the above negative metal; or an alloy of

65 parts of copper,
31 " zinc,

as positive metal, and an alloy of

12 parts of antimony,
5 " zinc,

as negative metal.

The bars are not soldered together, but bound by means of screws.

The positive metal melts at about 1200° C., the negative at about 600° C.

As in this element it is only the heating of the positive metal which influences the development of electricity, the arrangement has been made that only this is heated, while the negative metal receives heat by conduction. By this arrangement it is possible to apply temperatures of even 600°, and consequently to attain greater differences of temperature.

An interesting illustration of the conversion of heat into electricity is the fact that the water which is used for cooling the second

point of contact of the element becomes warm very slowly as long as the circuit is closed, but pretty rapidly if it is open.

The thermo-pile in question was constructed with a view to being used with a gas-flame. The individual elements consist of bars of unequal dimensions. The positive electrical bar is 7″ long, 7″ broad, and ½‴ thick; the negative electrical bar is 6″ long, 7″ broad, and 6‴ thick. Thirty-two such elements were screwed together, so that all positive bars were upon one and all negative on the other side, and thus had the form of a grating. The battery consists of two such gratings, which are screwed together in a roof shape, and are strengthened by an iron bar. As an insulator between the iron bar and the elements, mica was used. Besides this, the elements, where they came into contact with the cooling water, were coated with soluble glass. An earthen vessel filled with water was used for cooling the lower contact sides of the elements. The entire battery has a length of 2 feet, a breadth of 6 inches, and a height of 6 inches.

M. Marcus communicated further that he had constructed a furnace which was intended for 768 elements. They represent a Bunsen's zinc carbon battery of thirty elements, and consume per diem 240 pounds of coal.—*Sitzungsbericht der Akademie in Wien*, No. 8, 1865.—*Philosophical Mag.*, vol. xxix., No. 197.

Petroleum as a Steam Fuel.

From the Practical Mechanic's Journal, March, 1865.

Under the above title a cotemporary journal, "*The Engineer*," (27th January, 1865,) utters a decisive condemnation of liquid fuels for steam navigation. The article, a leader, is powerful in the way of assertion, and, beyond measure, severe in its strictures on those who are here unorthodox in its eyes, all of whom are classed amongst those "who dabble a little in the laws of nature, and possess the unenviable notoriety of being amongst the most credulous of mankind." The man who seriously proposes to substitute liquid for solid coal as steamship fuel is, according to the writer, only worthy to be classed amongst the alchemists, if even his moral condition would entitle him to keep company with that very harmless class of enthusiasts, supposing any such to be in existence.

We must say this article seems to us written with much less than the usual discretion and ability of *The Engineer*, and to be one calculated to obstruct progress. It does not even cross the threshold of the real questions, upon the issue of which depends the success or otherwise of the attempts that will, notwithstanding its denunciations, be made to ascertain whether or not it be a fact, that real and great advantages must accrue whenever the means shall have become practically perfect for using liquid fuel for steam navigation.

It is nothing in point to urge that "dabblers in science" have attributed fabulous heating powers to petroleum, or other analogous liquid fuels. We are quite content to accept for the moment as ap-

proximately true the estimate of heating power given by the writer in *The Engineer*, and to assume that petroleum consists of about 85 carbon and 15 hydrogen by weight, and that steam coal, on the average, may be taken at 80 carbon and 5 hydrogen.

We are also willing, for the moment, to suppose that the estimate is correct as to the heating power of each fuel, based on the premises that the combustion of one lb. of pure carbon is equivalent to 11·194·-000 foot pounds, and that that of an equal weight of hydrogen is four times as much. We are not to be understood as pledging ourselves to any of these figures, especially the last, which we deem largely below the truth. We simply take these data for the moment as presented to us, and accept *The Engineer's* conclusion from them—that the heating power of equal weights of petroleum and of coal are as 162 to 115 nearly, or as 1·4 to 1. This assumes, of course, that in both cases the combustion is *absolutely perfect.*

This alone does seem to us rather a striking *prima facie* case in favor of the petroleum—that its absolute heating power is admittedly nearly once and a half that of an equal weight of coal, But we have some elements to take into view before any such comparison can be practically even near the truth.

Petroleum may be viewed as simply a hydro-carbon ; as *The Engineer* fairly puts it, 85 carbon + 15 hydrogen = 100. But the steam coal, as also fairly put by the writer, at 80 carbon + 5 hydrogen = 85, contains of oxygen, nitrogen, sulphur, and mainly ashes, no less than 15 per cent.

Now, no one will affirm that these incombustible parts are of any service whatever in the fire, although, if we burn coal, we cannot keep them out of the grate ; hence, we must deduct at once fifteen per cent. of the absolute heating power in order to get the *practical heating value* of the coal. This would bring the relative heating values of the petroleum and coal to the ratio of 1·6 : 1. But there is a further correction. This 15 per cent. of ashes and inert matter in the steam coal, is not simply so much *useless or inert* material put on board and carried about—it is 15 per cent. of positively hurtful and waste-producing material, inasmuch as the whole of it must be heated up to the temperature of the furnace, and thrown off at that of the chimney; and to so heat it up, a certain increased portion of the otherwise available fuel must be burnt, just as in consuming wet wood one portion of the mass is burnt merely to evaporate the water out of the rest, and bring it to a state to burn and evolve its heat.

Now, dealing with the rough figures that we have here commenced with, it is not worth while to attempt any exactness as to how much of the 85 per cent. of real fuel in 100 lbs. of steam coal must be consumed to heat up to, say 2000° Fahrenheit, the 15 per cent. of rubbish it contains, very little of which ever comes back to the boiler. But, even when we shall have got this element into figures, we are not done with the coal. From the inevitable conditions of its combustion upon the set of grate bars, no precaution, no construction, can prevent more or less of the fuel dropping through into the ash-pit in an

unconsumed state, either as small coal, as coal dust, or as small cokes, These get mixed up with the ashes, *i. e.*, the really earthly contents of the fuel, and are with them thrown overboard.

We have, however, over and above all this, the losses produced by the imperfect combustion of the coal, and its sublimation, into the states of black soot and volatile oils (quite of the nature of petroleum) which fly up the funnel.

From the last three sources of loss, and others due to coaling and stowage, &c., together, the estimate recently given in the discussion of Captain Selwyn's paper on petroleum fuel, read at the United Service Institution, namely, that out of every five tons of steam coal purchased to be put on board, only four tons are really utilized, is one probably not materially in error. If this be so, as we are here comparing one fuel, (the liquid,) in which we will at present assume there is *no* waste, with the other, coal, upon which there is a waste of one-fifth, so may we at once add one-fifth to the absolute heating power of the petroleum, as representing then its practical efficiency as compared with coal. We then have, in relative value as fuel, petroleum : coal :: 2·68 : 1·00, or for equal effects.

Let us now come to the question of stowage. *The Engineer* admits 48 cubic feet for the ton of coal, and 44 cubic feet for the ton of petroleum. Accepting again these data, we find that *equal bulks* of petroleum and of coal, when stowed on board, will produce useful effects as fuel, in the ratio of 1·83 : 1·00. In other words, heating power and stowage considered together, the petroleum is *nearly twice the value* of coal for steam navigation.

But we are not done yet with the comparison. As the tonnage of any steamship is a constant quantity, whatever we save in stowage of fuel may be devoted to stowage of cargo, and thus we may either increase our power and our speed in a ratio approaching that of 1·83 to 1·00, or, at the old power and speed, we may stow additional cargo to the extent of about one-half of the bulk of the original coal bunkers. This will be *paying* cargo, and as a result, we must carry to the credit of the petroleum a still further augmentation of its figure of value, the precise amount of which can only be determined by the conditions, mercantile and otherwise, of any given example.

We have deduced everything thus from the data admitted by the writer in *The Engineer*, and we are quite content with the result. Were we, however, to proceed to what we should deem a precise and trustworthy comparison, upon more exact data, the case would assume even more favorable conditions as respects liquid fuel.

We have said that we have assumed no waste with liquid fuel. We have rightly done so, for with such fuel waste is impossible. It *must* be *perfectly* burnt, or accidents must result. It must not be spilled about or lost, or leaked away for the very same reason.

It thus becomes quite absurd and beside the point to make objection to the future practicability of using this liquid fuel, *based* on the *assumption* that it is to be stowed in our existing construction of ships, and burnt in our existing types of boilers and furnaces. Nor is this a

question that admits of being justly considered upon the basis of mere theoretic proportionate value of petroleum and of coal. It is eminently a practical question, and, like all such questions, is full of compromises and conditions balancing and affecting each other, the total of which must be taken into account. Thus, for example, a steamboat running short trips, with intervals of rest, can at present do no more than bank the fires, and cover the funnel top in such intervals, but the mass of fuel is alight, and, do what we may, will slowly consume, or go out altogether. If petroleum be the fuel, the flame can be shut off like a gas-light, or brought to a point only just to keep up steam. Here *may* be great economy; here may be advantages for war purposes scarce calculable, yet this is but an adventitious condition affecting differently the two fuels, whether they are relatively, *per se,* theoretically good or bad.

The stowage of petroleum must be in cells—not tanks—formed between an inner and outer skin of the bottom of iron ships, and divided by the continuous keelsons, and by several cross diaphragms. No practical engineer can be found who will deny the perfect facility with which such cells can be made vapor tight, even against a considerable tension; nor that any mechanical difficulties will be experienced in providing these with valves and cocks, &c., by which each can be filled and emptied separately if desired; and with the means of knowing precisely the volume, temperature, and state of the liquid within each, without access to or opening into the interior. Whether such closed cells be quite full or nearly empty, or whether their contents be churned or shaken up by the most heavily pitching or rolling ship or not, matters nothing.

The petroleum must be pumped in, or passed in any case through appropriate mains; and to make it available as fuel on board, measured volumes of it must be continually pumped out, and delivered at the point of combustion. Arrived there, it must be *met by measured volumes of air*, whose current through the flues and up the funnel must never intermit. In one word, the petroleum brought into a state of vapor must, at the point of ignition, be brought into contact with the requisite volume of air; and the combustion must be perfect—devoid of all smoke, like the flame of a well-trimmed naphtha lamp, and equally devoid of waste, by being mixed with a needless volume of air.

To effect these conditions, it is scarcely necessary to say that our present types of marine boilers are wholly unsuited. No alterations possible on existing boilers will meet all the requirements; for special apparatus is required, not only for the combustion of a fuel, the whole of which will disappear in flame, but for the absorption of the intense heat poured forth with great rapidity by this flame.

Marine boilers for the economical consumption of petroleum fuel must be contrived that shall admit of the entire length of these flues or tubes—from the first combustion point to the base of the funnel being constantly filled with a brilliant and intense *flame*, and the water spaces, etc., must be so arranged as to permit free escape to

the increased volumes of steam that will be delivered from surfaces thus rapidly receptive of heat.

The temperature of hydro-carbon flame, when perfect, is probably not inferior to that of the ignited solid fuel in the marine boiler furnace, if not superior to it. There will be a vast difference in steam producing power, within the same total bulk of marine boiler, between the best existing types, in which the gases of the fires meander through the soot and dust-lined flues and tubes at an average temperature of only about a low red heat at best, and a new type, constructed with great receptive surfaces, always rigidly clean, and free from jacketting inside with soot or dust, and filled with flame from end to end, as bright and hot as that of an oil gas argand burner.

This is a thing of the future, no doubt, but it presents nothing impracticable, because nothing contrary to nature's laws; nor does its accomplishment present anything like the difficulties that beset every attempt to "consume smoke" from coal on board steamships. To effect this, real difficulties are imposed by the very nature of the solid fuel, and the necessity of passing through it an enormous and unmeasured volume of air, which have no existence in respect of liquid fuel.

In the very rough comparison of effective value we have made, based upon our respected cotemporary's data, we have not alluded to the enormously better boilers for economizing heat, that liquid fuel will not only admit of, but compel. At present every part of flue or tube must not only be so circumstanced that it can be got at for repair; it must be also capable of being swept or brushed free of soot and ashes. The draft, as at present produced by a low funnel, almost always inadequate to perfect combustion of coal fuel, involves likewise large flue or tube areas, the surfaces of which are always sullied, so as to be bad absorbers of heat.

Except as respects capability of repair, all these arrangements may be changed; and, with surface condensation and fresh water in the boilers, the construction of the latter may take the type of the locomotive, with enormous and most effective expansions of tube surface. Artificial drafts, however produced, will be found, we think, indispensable; and as a result, the existing huge, lumbering funnels, rising 30 or 40 feet above the deck, will disappear, and their place be supplied by comparatively small tubes, just enough to emit the transparent water vapor, carbonic acid and nitrogen, which will constitute the bulk of the evolved products of the combustion. These tubes need not rise above the deck higher than shall carry these vapors or gases clear of persons on deck. There will be no smoke.

Hitherto we have alluded only to the advantages in a mercantile sense, consequent upon the successful use of liquid fuel for steam navigation. For purposes of naval warfare, however, its advantages can scarcely be at present fully foreseen.

If liquid fuel be weight for weight about twice the efficient value of coal, then a blockading steamship can keep her post off an enemy's coast twice as long without replenishment, using such fuel, as if she

used coal; or, she can make twice as long an ocean run as with coal. No column of smoke streaking the horizon will tell of her presence, before she desires, to an enemy watching to escape.

We have used the word petroleum throughout here, because shortly it expresses, though badly, what we are treating of.

We look however to the future of liquid fuel taking its supply, not from natural oil wells, or at least not from these alone, but from liquid hydro-carbons, to be artificially produced by the distillation at low temperatures (not exceeding a low red heat) of the very worst and most worthless refuse small coal of our coal fields. Fuel thus at present absolutely and heedlessly wasted, such as the mountains of small coal and dust at the pit-heads of most of the northern collieries, will become convertible in part into a combustible of the highest value, and of the greatest portability. We have no doubt, too, that in the time to come, though yet a distant one, means, the general nature of which we can even already discern, will be devised by which our *very* thin seams of coal, such as those of Staffordshire, that are too thin to bear the cost of working at all, by ordinary methods, shall be so arranged that by their own slow combustion *in situ*, when once set alight, and supplied in proper air courses and galleries by downcast shafts with suitable volumes of air, they shall evolve at the mouths of upcasts immense volumes of hydro-carbon vapors, only requiring condensation to fit them for liquid fuel.

To the savage man, fuel of any sort, or its use, are incomprehensible mysteries; to a not very remote generation of our own ancestors, coal, as a substitute for wood or peat, was held a mischievous and deleterious refinement; to some at the present moment, the substitution of liquid coal (for what is petroleum but that minus a little carbon?) presents itself as an equally absurd and preposterous, because new, attempt. Yet we venture to predict that a not *very* distant age will see coal as fuel employed in no other shapes, but after preparation, and either as liquid hydro-carbon distilled from the raw coal, or as carbonic oxide and other combustible gasses produced from it, and used alone as fuel, by methods analogous to those of Mr. Charles Siemens.—Ed.

Platinum Mirrors.

From the London Journal of Science, July, 1865.

M. Dode, a French chemist has introduced platinum mirrors, which are greatly admired, and which present this advantage, that the reflecting metal is deposited on the outer surface of the glass, and thus any defect in the latter is concealed. The process, which is patented in France, is described as follows: Chloride of platinum is first made by dissolving the metal in *aqua regia* and driving off the excess of acid. The neutral chloride is then dissolved in water, and a certain quantity of oil of lavender is added to the solution. The platinum immediately leaves the aqueous solution and passes to the oil, which

holds it in suspension in a finely divided state. To the oil so charged the author adds litharge and borate of lead, and paints a thin coat of this mixture over the surface of the glass, which is then carried to a proper furnace. At a red heat the litharge and borate of lead are fused, and cause the adhesion of the platinum to the softened glass. The process is very expeditious. A single baking, M. Dode says, will furnish 200 metres of glass ready for commerce. It would take fifteen days, he says, to coat the same extent with mercury by the ordinary plan.

Preservation and Amelioration of Wines by Heat.

Accepting the theory of M. Pasteur that the deterioration of wines is caused by the propagation of certain mycoderms, M. de Vergnette-Lamotte experimented on the effect of a high temperature continued for a considerable time upon the French wines. The effect of high atmospheric temperature upon Sherry and Madeira has long been known and made available by connoisseurs. A number of bottles of Burgundy, containing 12·8 per cent. of alcohol, and of a fine reddish violet color, were exposed for two months to a temperature which was not allowed to exceed 122° Fahrenheit, (50° Centigrade.) The wine had lost its color and its fruity savour, and somewhat resembled the Spanish wines. By prolonging the experiment for a year, the wine had entirely lost its color and had taken the tint known as onion-skin; it had deposited abundantly, and appears to be entirely preserved, while the bottles of the same lot which had been left in the cellar without heating, had become sickly and was worthless. It is doubtful whether a process by which a Burgundy wine is converted into something resembling Sherry will meet with much favor in France.

Erosion of Lead.

From the London Mechanics' Magazine, August, 1865.

The erosion of lead, and even of type metal, by certain species of insects, is not generally known, and may be extremely mischievous. Not long ago it attracted the attention of the French Academy of Sciences, and several communications respecting it have been published with their proceedings in the *Comptes Rendus.* Of these the following is a *resume:* In 1858 Marshal Vaillant exhibited to the Academy leaden bullets brought back from the Crimea, in some of which the larvæ of insects had excavated circular passages three or four millimetres in diameter, and in others superficial grooves. Inquiry was made through the Russian Ambassador, M. de Kisselef, whether similar erosion had been observed in Russia. M. V. de Motschulsky replied that nothing of the kind had been detected in the cartridges of the Russian army in the Crimea, and that the insect which had caused the injury appeared to be very rare in Russia, not having been discovered by Russian entomologists in the Crimea. It is stated to be very common in England, Sweden, and Germany, and

to occur in the Jura in France. It attacks silver firs and pines. The insect which damaged the French cartridges was imported from France in the wood of the cases in which they were packed. All the excavated passages were originally circular in section, and those that were semi-circular in section, that is, superficially grooved, were only segments, of which the other half was in the contiguous surface of other bullets, or of the wood forming the sides of the cases. The passages were always open at both ends. Excavation was effected by the mandibles of the insect, the apparatus consisting of a saw-tooth, and cut like a file. The insects do not eat the lead, but simply bore it out; and it was observed that their remains, after metamorphosis, had been carried downwards by the particles of the metal, reduced to powders, and dispersed on the outside through the cracks, in the bottom of the packing case. The perfect insects did not attack the lead, but died in the passages, even immediately after their complete metamorphosis, as very often occurs with insects in general.

In 1833 Audouin exhibited to the Entomological Society of Paris sheet lead from the roof of a building deeply grooved by insects. In 1844 Desmarest mentioned erosions and perforations of sheet lead by a species of Bostriche, and illustrated the fact by cartridges from the arsenal at Turin. Mr. Westwood, the well-known British entomologist, has recorded observations by himself on the perforation of lead by insects. M. Bouteille, curator of the Museum of Natural History at Grenoble, sent to the French Academy of Sciences, from the collection under his charge, specimens of cartridges gnawed by insects, which were found *in situ*, and the following report upon the subject was made by Marshall Vaillant, de Quatrefages, and Milne Edwards: The insect *Sirez gigas*, a large hymenopterous species, which, in the larvæ state, lives in the interior of old trees or pieces of wood, and which, after the completion of its metamorphosis, quits its retreat for the purpose of reproduction. As previously stated it cuts its way by its mandibles, gnawing the woody substance or other hard bodies which it meets with in its course. Analogous perforations are made by the mandibles of the *Callidium saguineum.* The reporters add: "If it is probable that it is always with their mandibles that coleopterous as well as hymenopterous insects thus attack lead or other hard bodies, it is not well established that it is always the desire of liberty which prompts them so to act. Indeed, in some cases, coleopterous insects have been seen to gnaw the exterior of similar bodies." Reference was made to a paper by Antonio Berti on the perforation of leaden pipes by an insect named *Apate humeralis.*

Scheurer-Kestner, in 1861, communicated to the French Academy a notice of the erosion by an insect of the sheet lead of a new sulphuric acid chamber. The creature was caught in the act of escaping through the lead, having been imprisoned between it and a wooden support. Perhaps the most interesting and important case of insect erosion is that of stereotype metal, which was communicated in 1843, by M. du Boys, to the Agricultural Society of Limoges. Specimens riddled were also exhibited.

On the Specific Refractive Energies of the Elements and their Compounds.

From the London Chemical News, No. 286.

Dr. J. H. Gladstone delivered a discourse in which he described the further results of the conjoint labors of himself and the Rev. T. P. Dale, M. A., in a branch of physical research which had been already sketched out in a paper read before the Royal Society, in March, 1863. Since the date of this communication, the subject had been taken in hand by Landolt, who adopted a mode of working very similar to that of the author's. The "specific refractive energy" of a body is a constant, not affected by the temperature, and is arrived at by dividing the refractive index of the substance (μ) minus 1, by the density. The formula already proposed was found to hold good on a more extended investigation of the subject, and the authors generally worked with the fixed line A. The proposition resolved itself into a study of the inquiry whether the specific refractive energy of an element was invariable under all circumstances of isolation or combination, and whether this property in the case of a compound was correctly expressed by taking the means of the refractive energies of its several elementary constituents. As a general rule this was found to be the case, but the authors brought forward a few exceptional instances which at present appeared to stand in opposition to their statement. Dr. Gladstone particularly referred to sulphurous acids, and aqueous tartaric acid, as presenting anomalies which were considered worthy of more extended investigation, with the view of determining the nature of the disturbing causes. This mode of physical research was interesting in connexion with the study of isomerism, and would probably lend valuable aid in determining the internal constitution of bodies; thus, whilst aniline and its isomer, picoline, gave widely different results under this optical treatment, it had been found by Landolt that a mixture of equal equivalents of methylic alcohol and acetic acid behaved precisely like its theoretical conjugate, glycerine! Dr. Gladstone exhibited in a tabulated form the numbers representing the specific refractive energies of many of the elements, multiplied by their atomic weights, or "refraction equivalents," as Landolt terms it, and he worked several examples by way of showing the application of the formula, and the mode of deducing from compound bodies the value of each constituent. The table stood thus:

Name of element.	Refraction equivalent.
Carbon,	5·1
Hydrogen,	1·5
Oxygen,	3·0
Nitrogen,	3·3
Chlorine,	8·5
Bromine,	15·7
Iodine,	24·4
Sulphur,	16·0
Phosphorus,	18·6
Tin,	22·0
Sodium,	6·0
Mercury,	11·0

With regard to the valve of carbon it was shown that the number observed in the case of the diamond agreed with the results deduced from the examination of carbonic oxide, carbonic acid, olefiant gas, and a variety of liquid hydro-carbons. Hydrogen did not appear to have precisely the same value in the form of gas that it had in certain hydrogen compounds, and the author stated that 7·6 was the average expression from a great number of experiments, of the value of $C\,H_2$, the oft-quoted increment of carbon aud hydrogen in the homologous series. Nitrogen in the form of gas was 3·3 as above, but in combination its value sometimes amounted to 4·2. In a similar manner the numbers representing oxygen and chlorine gases became subject to modification when those elements were combined.

The President said he had listened with much pleasure to the author's interesting communication, and he wished now to inquire of Dr. Gladstone whether there appeared to be any relation between the remarkable exceptions noticed by him, and their observed atomic volume. It was known that oxygen in combination occupied two different atomic volumes, and he thought it possible that there might be some connexion between the volume and refractive energy in this and other similar instances.

The Rev. Thomas Pelham Dale gave an account of the mode by which these conclusions had been arrived at, stating that Dr. Gladstone usually undertook the experimental, and himself the mathematical department of the inquiry. The formula adhered to in calculating the refractive valve was

$$\mathrm{I}\frac{\eta-1}{d}=c,$$

and the speaker insisted upon the importance of selecting bodies of refractive indices—such as bisulphide of carbon—for the purpose of testing the accuracy of the proposed theory. The liquid named was readily procured and purified, and its refractive index for the red rays was 1·6, and for the violet 1·7. Errors might arise from inaccuracies of adjustment, or from an elevation of temperature in the liquid contents of the prism by the passage of the solar beam; but Dr. Gladstone had employed a liquid septum—such as alum solution—in order to cut off the heat rays, and it was not possible that the figure of the hollow prism underwent any sensible alteration during the experiments, inasmuch as frequent observations made with the same liquid gave closely concordant results. He would, however, recommend the use of a prism of 60 degrees, or an equilateral triangle, and make three independent observations, changing the angle each time, and then take the mean of the three results.

Dr. Frankland had hoped that the optical results would have suggested an explanation of the difference observed in the chemical properties of carbon in the form of carbonic oxide, and the more active state of that element existing in combination with hydrogen in olefiant or marsh gas. It appeared that the specific refractive energy remained constant throughout, and that optically there was no distinction between one and the other form of carbon.

Dr. GLADSTONE replied that his experiments did not indicate the well marked chemical difference to which Dr. Frankland had alluded. The speaker offered some further remarks with reference to the details of the optical arrangement, and stated that M. Landolt and Professor Stokes had seen no theoretical difficulty in accepting the proposed formula.

The PRESIDENT then moved a vote of thanks to Dr. Gladstone and Mr. Dale for their interesting communication, which was warmly responded to, and adjourned the meeting until June 1, on which occasion he would have the honor of addressing the Society upon the subject of "*The Analysis of Potable Waters.*"

Lead Poisoning.

From the London Mechanics' Magazine, August, 1865.

Poisoning by drinking water which has acted on lead, happens far more frequently than is often suspected, and the mode in which the water is rendered poisonous is frequently difficult of discovery. A correspondent of the *Times* states that, from a rural parish where the drinking water is got from draw wells, and there are neither leaden pipes pumps nor leaden pipes to contaminate the water, several of the peasantry went lately to the neighboring county infirmary suffering from lead poisoning. Careful investigation led to the discovery of the evil—the so-called "tinned" kettles in which the water used for tea and for cooking was boiled. It was ascertained that the "tin" with which the kettles were lined was an amalgam of tin and lead. The adulteration of tin with lead is one of the most common frauds. It is of very great importance to public health that some way of escaping from poisoning by leaded tin should be discovered, and it would be desirable that we should know whether there is any coating for iron which would resist heat and the ordinary action of water, and which could be substituted for what is called "tin." About a year ago a French patent was taken out for such a coating, and the coating is said to have stood very severe tests of heat and acids. Such a coating has also been discovered lately in England. Any one giving accurate information respecting such coatings, would confer a boon upon the public. A very ready test for lead in water consists in taking two tumblers and filling one with water which is known not to have been in contact with lead, the other being filled with the suspected water. Dissolve in each about as much bichromate of potash as will stand on a groat. By daylight the water in each tumbler will be of the color of pale sherry and water. Cover the tumblers so as to keep out dust, and let them stand in a warm place in a room with a fire in it for twenty-four hours. If the suspected water be free from lead, it will still have the same color as the other, but if there be lead in the water, it will have a more or less opalescent tint, as if a drop or more of milk had been put into it. If there be a great quantity of lead in the water, a very slight film of lead will be deposited on the glass.

For the Journal of the Franklin Institute.

Atmospheric Pressure as a source of Mechanical Power.

In the concluding paper on this subject in the July number of the *Journal*, a passage was accidentally omitted in the copy sent. Its point is too pertinent, if not too important, to be entirely excluded:

It was observed that the two forces in steam bear the same relation to each other as action and reaction—that in a cylinder with a piston of fifty inches area, and worked with steam of four atmospheres, or 60 lbs. on the inch, the pressure on the piston would be $50 \times 60 =$ 3000 lbs. On the other hand, the fluid on leaving the cylinder would dilate and fill four of the same dimensions; hence $50 \times 4 \times 15 =$ 3000 lbs. of atmospheric pressure. But while the forces are theoretically equal, in practice the contracting one is (what few would suspect) the most productive, and, in some cases, to an extent that not many would credit. The truth, however, is that more power—15 lbs. on the inch more—may be obtained from condensing steam of two atmospheres and upwards, than from its direct pressure. This signal result is due to the fact that a cylinderful of low or common steam has no expansive power at all to move the piston, while it is all that is required to produce a vacuum under it. In the above example the acting expansive force is credited at 3000 lbs., but in reality it should be held at 2250 lbs., for, as the piston acts against the pressure of the atmosphere, 15 lbs per inch is consumed in overcoming that, leaving, as the effective force, 45 lbs on the inch, instead of 60 lbs. It is, therefore, palpable that at every stroke of a piston moving by the direct pressure of the fluid, a cylinderful of it of one atmosphere, or of 15 lbs. on the inch, is virtually lost.

The piston of an engine working with steam of two atmospheres, or 30 lbs. on the inch, has only 15 lbs. productive pressure, while the condensation of the fluid produces a vacuum under a piston of twice the area of the other, thus evolving a force by condensation actually double that of expansion.

Another fact to which I do not remember to have seen any reference: When expansion by cut-offs in the working cylinders of the present condensing engines is not carried down to zero—something bordering on the impracticable—all the steam over and above that, is not only lost, but the expense of its condensation thrown away. Were this source of waste of fuel, and of power thoroughly laid open, (see Mr. Lewell's remarks, page 39,) it would be startling. By the plan proposed—see July number of the *Journal*—it is annihilated.

*

Strength of Steam Boilers.

From the London Artizan, August, 1865.

In another column our readers will observe the reported explosion of a large Cornish boiler, and as this appears to have been due to deficiency of strength originally in the flue tube, it appears to us not

inappropriate to offer some remarks as to what course should have been adopted in order that the boiler might be competent to withstand the ordinary pressure to which it was intended to subject it. The locus of failure was in the internal tube, which was far too weak to bear the strain, which was "50 lbs. and upwards per square inch," the dimensions being as follows: Internal tube, 4 feet in diameter, 32 feet in length, and $\frac{7}{16}$ of an inch in thickness. This tube collapsed completely from one end to the other, as the calculations given below will show was the result to have been anticipated.

There were two ways in which the flue might have been made stronger; first, by using thicker plates in its construction; second, by attaching stiffening rings to support it, virtually, in fact, dividing it into a series of shorter tubes, and so increasing its strength.

The formula used below is a *practical* one for *working* strength based upon the data obtained by Mr. William Fairbairn, C.E., from his experiments upon the resistance of tubes to collapse under external pressure.

Let $t =$ thickness of metal in inches.
$l =$ length of flue in feet.
$d =$ diameter of flue in inches.
$p =$ pressure in lbs. per square inch.

Then,

$$t = \sqrt{\frac{p\,l\,d}{161200}}.$$

First, taking the flue as not being stiffened by rings, the thickness of metal requisite would be thus determined,

$$t = \sqrt{\frac{50 \text{ lbs.} \times 32 \text{ ft.} \times 48 \text{ in.}}{161200}} = \sqrt{\cdot 476 \text{ in.}}$$

and

$$\sqrt{\cdot 476} = \cdot 6902 = \frac{10\cdot 04}{16} \text{ in.,}$$

whereas the actual thickness, as stated above, was but $\frac{7}{16}$ in.

The actual pressure which might have been safely put upon the flue may be determined by transforming the formula thus,

$$p = \frac{161200\, t^2}{l\, d}$$

in the present case,

$$p = \frac{161200 \times 49}{10 \times 48 \times 256} = 20 \text{ lbs. nearly,}$$

and this is, probably, as high a pressure as such a flue should have been regularly exposed to.

If the thickness of $\frac{7}{16}$ in. had been retained, and the tube strengthened by the second method, inserting stiffening rings, so as to reduce

the effective length of the flue as regards its resistance to external pressure to 10 feet in each length, the safe working pressure would have been

$$p = \frac{161200 \times 49}{32 \times 48 \times 256} = 64 \text{ lbs. nearly.}$$

It is here worthy of comment that there appears to be a great tendency to overstrain the materials used in the manufacture of boilers, which does not occur in the construction of other works wherein the same materials are used, although, as in the case of iron bridges, the risks would probably be less in reducing the strength, than in making boilers too weak; but then, it is to be remembered that iron railway bridges are always subject to severe tests, and undergo a rigid examination by a government inspector before they are allowed to be applied to public use; and it seems very desirable that some similar course should be adopted in regard to boilers, whereby a considerable diminution of loss of life, &c., might be effected.

It is tolerably certain that there are many cases of boiler explosions in which the boiler itself has been amply strong, the accidents being due to a combination of circumstances quite unanticipated and beyond control, but such an explosion as that above alluded to, can only be traced to neglect of the proper precautions which should have been adopted in the construction of the apparatus.

Furthermore, in the comparison of bridges with boilers, it is evident the latter are much more liable to deteriorate in the strength of their materials than the former, as the influences to which they are subject are of a more destructive character than those which affect the former, while their depredations, being out of sight, are exceedingly liable to be overlooked, until they have progressed to such an extent that they render themselves evident by giving rise to some appalling accident.

Of course, a frequent systematic examination will do much towards the diminution of the number of explosions, and it is not improbable that in the accident above referred to, some depression in the tube might have been noticed previous to the total collapse, in which case, by the application of proper means—such as stiffening rings—the catastrophe might have been avoided and the flue rendered safe.

Such occurrences supply valuable experiences which *ought not* to be lost upon manufacturers and users of steam apparatus, but it is to be feared that, as a rule, they produce but temporary impressions, passing away with the remembrance of the accidents creating them.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, September 20th, 1865.

The meeting was called to order with Prof. John F. Frazer, Vice President, in the chair. The minutes of the last meeting were read and approved. The minutes of the Board of Managers and of the various

Standing Committees were reported, including the following donations: From the Royal Geographical Society, the Royal Astronomical Society, the Statistical Society, the Institute of Actuaries, and the Zoological Society, London; Col. Richard Strachy, through the Asiatic Society of Bengal, Calcutta; the Canadian Institute, Toronto; the Natural History Society, Montreal; the Literary and Historical Society, Quebec, Canada; and Wm. Biddle, Sol. W. Roberts, and Professor John F. Frazer, Philadelphia.

The Special Committee on Steam Expansion reported progress of their experiments.

The usual special paper for the evening was omitted through the unavoidable absence of the gentleman who had been appointed to read it.

The report of the Secretary on new inventions and discoveries was then in order and was read as follows:

Secretary's Report.

Mechanics.—We have received a communication from Mr. T. McDonough, of New York, on the subject of certain experiments in the effect of mixing air with low pressure steam.

The apparatus used was of a simple form. Steam was generated in a small boiler and allowed to escape through a nozzle so as to strike upon the fans of a little air-mill. The quantity of steam escaping in a given time, and the number of revolutions produced in the air-mill by this means were determined in the first place by direct experiment.

Air from a gas holder under moderate pressure was then allowed to flow into the rear of the same jet and issue with the steam.

The amount of air so added, and the number of revolutions in the air-mill during a given time being again determined, it was thus found that the addition of a small amount of air, say $\frac{1}{10}$ that of the steam, would increase the number of revolutions in the mill by a much greater quantity, as in this case by $\frac{1}{4}$.

The following table will exhibit the result of many experiments:

Table *of Experiments in Mixing Air and Steam.*

Revolutions of wheel per minute,	60	60	60	60	60	60	60	60	60	70	60	84	60	86
Cubic inches of steam per minute,	432	432	432	432	432	432	432	432	432	504	432	604	432	619
Inches of air added per minute.	43	60	83	120	150	200	40	66	55	85	66	100	85	120
Motion of wheel with steam and air,	73	90	91	120	165	164	74	107	98	111	80	180	99	150
Gain by adding air over what is due to increased volume,	0·29	·23	·17	·37	·61	·56	·39	·44	·30		·25		·14	·32

Example.—In first column, by adding 43 inches of air to 432 of steam, the wheel increases its speed from 60 to 73, or about one-quarter for an added volume of one-tenth.

This action it is, moreover, proposed to apply to steam engines by so arranging the valves, &c., that air in place of steam will be admitted during the first part of the stroke, after which the steam will be admitted and mix with this air.

We should remark in this connexion that the above experiments and results do not stand alone, but are supported by other independent

investigations. Thus, similar facts have been observed in connexion with a small steam turbine, by Prof. R. E. Rogers, of the University of Pennsylvania, and a plan for using air and steam together mentioned in the London *Mechanics' Magazine*, January, 1865, page 7, points to some observations in the same direction.

In explanation of some of these experiments, it may be suggested that the introduction of cold air might condense some portion of the steam, so causing it to be projected in liquid drops against the wheel, by which means its motive power would be more efficiently applied than when it issued as an expanding and diffusable vapor.

Mr. Nystrom here remarked that the increased density of the mixed air and steam might account for the gain in effect.

The apparatus referred to above was explained by means of a drawing made upon a plate of glass (coated with a colodion film, which had been sensitized, exposed, and developed in the usual manner) placed in a powerful lantern, by which a greatly magnified image was thrown upon a screen conveniently adjusted, and thus made distinctly visible to all in the room. The apparatus next to be described was illustrated in like manner, and it is the intention of the Institute to place this mode of demonstration at the command of all who may require it at their meetings.

The next point noticed under the head of "mechanics" was the low water signal of Shaw and Justice. This consists of an ordinary steam whistle attached to the boiler by a tube reaching to the lowest safe water line, and having those parts immediately below the bell of the whistle, filled with resin. So long as the water line in the boiler is above the lowest safe level, the tube leading to the whistle is filled with that fluid, which, by reason of its restrained circulation, &c., will not carry up heat enough to melt the resin. When, however, the water falls below this point steam enters the tube, melts out the resin, and blows the whistle.

Glass Etchings.—At a previous meeting, the process by which crystals might be produced on plates of glass and their designs then etched into that substance, so elaborately studied by Kuhlman, had been described and specimens exhibited. It had since been found that such etchings formed beautiful objects for the magic lantern, the difference between the roughened and smooth portions producing on the screen all the distinction between black and white, with every variety of half tone and gradation.

(A number of these specimens, and the plates coated with crystals from which they were formed, were here exhibited in the lantern.)

Physics.—Many experiments have been made by Professor G. F. Ansell, of the Royal Mint, London, on the diffusion of burning gas and its kindred substances, fire, damp, &c., through various porous substances, including porous earthenware, graphite, and india rubber, with a view of arranging a piece of apparatus which might serve as an indicator of such dangerous substances when present in coal mines and other localities. Several instruments of different forms have been devised, all, however, alike in their dependence upon a well known action,

by which rare gases as a rule pass through a porous diaphragm into denser ones more rapidly than these last travel in the opposite direction.

By this means, if a vessel filled with air is closed by a porous plate or stopper as above described, and is introduced in an atmosphere of burning gas or the like, this last will enter the vessel more rapidly than the air will escape, so producing a pressure readily indicated by a water gauge or like instrument, which thus serves as an indicator of the gas in question.

India rubber, it appears from the above experiments, is decidedly pervious to burning gas; which shows us that the leakage of flexible gas pipes, so often complained of, is not always a fault of manufacture, but to some extent an unavoidable nuisance.

(The diffusion of burning gas through porous substances was here experimentally demonstrated.)

Spectrum Analysis of Heavenly Bodies.—In a previous report published in the June number of this *Journal*, we noticed some remarkable facts in relation to nebulæ which were pointed out in a communication to the Royal Society by William Huggins. From a more complete abstract of this paper we now call attention to some additional points of interest.

It would appear that out of some fifty stars, whose spectral lines were carefully studied, only two, α Orionis and β Pegasi, want the very distinct lines C and F, which indicate the presence of hydrogen. The lines which indicate sodium, magnesium, and iron seem universal, while there is much difference with regard to others.

There seems also reason to believe that the color of stars and planets may in some sort indicate the chemical condition of their atmospheres. Thus, in the planet Mars we find that the predominance of red light may be due to strongly marked groups of dark lines crossing the blue end of the spectrum, and indicating bodies which cut off these rays, and so leave the red vibrations unbalanced and in excess.

The same connexion has been observed between the spectra and tints of many colored stars, and is especially remarkable in the double star β Cygni, whose components are orange and blue, and whose spectra abound in dark lines across the blue end for the first, and across the red and yellow for the second.

Certain nebulæ, as was before stated, show in the spectroscope bright lines indicating a gaseous state, in place of the continuous spectrum crossed by black lines, which denotes a luminous solid, enveloped in a gaseous atmosphere. Some of these, as the great nebulæ in Orion, show three bright lines, of which two correspond with the brighter lines in the spectra of hydrogen and nitrogen respectively, the third not corresponding with any known element.

The annular nebula in Lyra and the dumb-bell nebula show only the line which indicates nitrogen.

In these cases what we may call the nitrogen spectrum, as given by the nebulæ, wants some bright lines which we might expect to see. The elementary character of this substance has often been questioned on chemical grounds. May this spectrum indicate the element of which nitrogen is a compound?

Electricity.—A new arrangement for developing electricity of high tension is announced by Prof. Julius Thompson, of Denmark.

The apparatus consists of a series of platinum or platinized plates, immersed in dilute sulphuric acid, charged in succession by causing an ordinary battery to pass its current through them, so as to develop oxygen and hydrogen respectively on alternate plates; they then act on the principle of Grove's gas battery. The transfer of the action of the charging battery from pair to pair of this platinum series is effected by a little magneto-electric machine, and is continued as long as the apparatus is in motion.

Glissler Tubes.—The manufacture of these beautiful pieces of apparatus still continues to improve. Larger and more beautiful combinations of form and color are continually appearing.

Two very beautiful specimens, imported by Chester & Co. of New York, were exhibited. One of these, nearly a yard in length, contained eight bulbs of canary glass, which, by reason of their fluorescent properties, glowed in the electric discharge like a string of emeralds. Another contained a colorless solution of quinine, to which, however, a beautiful blue color was imparted by its fluorescent action from the electric discharge.

Mr. Coleman Sellers remarked in this connexion, that, as was well known, these fluorescent bodies shone at the expense of the invisible but actinic or photographic rays, which they thus rendered visible by depriving of their especial properties and powers.

That this property was applied as follows: A plate of glass coated with a solution of quinine was substituted for yellow glass in photographic dark rooms, &c., and this, while allowing white light to pass, deprived it of its actinic power, and rendered it innocuous to sensitized plates.

Chemistry.—New processes for the preparation of oxygen. In the *Analen der Chemie and Pharmacie* for last April, appeared an article describing the following process for oxygen, by M. Fleitmann, which has been very thoroughly quoted in scientific and other journals: "Commercial chloride of lime, or bleaching salt, is treated with water, by which all its hypochlorite of lime (CaO,ClO) is dissolved. This solution is then decanted, and has a small quantity of the hydrated sesquioxide of cobalt mixed with it, and then being heated to 70° or or 80° Fahrenheit, disengages gently all the oxygen it contains. The same oxide kept moist may be used over again with fresh solution as often as desired. Oxide of nickel acts in a similar manner, but with less energy."

The action here described is a very remarkable one. The office of the oxide of cobalt being simply to take oxygen from the lime salt, and immediately to abandon it while returning for a fresh supply. The action is also curious from the ease with which it takes place, as is thus shown: We pour into this test tube a little of the lime solution, and then add a few drops of nitrate of cobalt. A black precipitate is at once formed, and immediately, without any application of heat, the liquid froths and gives off a gas which we easily prove to be oxygen by its power of relighting a smouldering match each time we introduce it into the mouth of the tube.

This action is peculiarly striking to the experienced chemist, who is accustomed to see oxygen liberated only by the application of a high temperature and with comparative difficulty. This process has been generally announced as a very economical one, far cheaper than the usual method with chlorate of potash, but our experiments do not support this idea. One pound of chloride of lime will yield but about $2\frac{1}{2}$ gallons of oxygen, while one pound of chlorate of potash yields about 30 gallons or 12 times as much. The cost of the materials is in the same proportion inverted, which makes the cost for the same quantity of oxygen equal in the two methods.

As regards convenience, the balance is decidedly against the new process. Each pound of the lime salt requires about a quart of water for its treatment, and we thus have the unwieldy bulk of nearly three gallons to deal with, while a pound of chlorate can be readily worked in a quart copper flask.

If we could obtain the liquid chloride of lime, (manufactured abroad but never imported,) which contains a double proportion of hypochlorite, this process would be of economic value. Our native limestones are found unfit for the manufacture of bleaching salts on account of the magnesia which is present in all of them.

Another process for oxygen is announced by M. Archereau of Paris. This consists in exposing a mixture of silica (sand) and sulphate of lime (burned plaster) to an intense heat in a peculiar furnace somewhat like Siemen's, when a silicate of lime is formed and a mixture of sulphurous acid and oxygen escapes,

$$SiO_2 + CaO,SO_3 = CaO,SiO_2 + SO_2 + O.$$

It is proposed to remove the sulphurous acid by subjecting the gases to a pressure of three atmospheres by which this gas is liquefied, which will facilitate the removal of the greater part, and absorbing the remainder in milk of lime.

It is stated that this process will furnish the gas at so low a rate, that it may be economically used with burning gas to make a lime light for the illumination of stores, which can be so lit better at a cheaper rate, than with the ordinary arrangement of simple gas burners. It is, moreover, stated that a company has been established to manufacture oxygen by the above process and furnish it to consumers.

Magnesium.—From experiments made by Dr. Thomas Woods, of Parsonstown, England, it would appear that the above metal evolves in burning more heat than any other substance. As this heat is developed in a short time, and concentrated in a small mass of matter, we seem to see here a reason for that *intensity* in the light developed by this body, or the rapid rate of its vibrations, which causes it to produce a spectrum abounding in the higher blue rays, to afford a blue-white light, and to exhibit remarkable photographic energy.

The ordinary lime light, compared with other artificial sources of illumination, shows a bluish tint, and is thus often used for moonlight in theatrical effects, but, compared with magnesium, its light acquires by contrast a red tone.

This comparison was then exhibited in a striking manner, by throwing the different lights upon the screen.

The rendering gunpowder non-explosive by mixing with it some incombustible powder, thus insulating the individual grains, proposed by Mr. Gale, of Plymouth, is one of the notable and ingenious novelties of the month not to be overlooked; and lastly, we would call attention to the statement that Mr. Horzeaux has proved, in certain cases, that the coloration of iodized starch paper exposed to the air is not due to nitric acid, but must indicate the presence of ozone.

After the conclusion of the Secretary's Report, Mr. Thomas Shaw moved that the powers of the Committee on Sound Signals be extended so as to include the discussion of color signals also. This motion was carried.

The meeting was then, on motion, adjourned.

HENRY MORTON, *Secretary.*

BIBLIOGRAPHICAL NOTICES.

The Cadet Engineer; or Steam for the Student. By JOHN H. LONG, Chief Engineer, United States Navy, and R. H. BUEL, Assistant Engineer, United States Navy. Published by J. B. Lippincott & Co.

Though "the royal road to learning," that is, the way of acquiring knowledge without labor and effort, is not and never will be open to travelers, there is a great difference between the new untrodden path to knowledge, and that which has been rendered firm to the foot and clear to the eye by the tread of previous students, and freed of some obstructions by their labors. As the friends of education, we therefore hail with pleasure such publications as the foregoing, which greatly aid students in the acquisition of knowledge, by placing the facts of their subject and the reasons and connexions of these in a simple and straightforward manner before the reader.

We cannot do better than give an extract from the table of contents, to show our readers the scope and character of the present work:

"Description and statement of advantages and disadvantages of engines and boilers.

"Appendages to engines and boilers."

"The Paddle-wheel; The Screw Propeller; Combustion of Coal; Erection of Engines; Exhaustion of Steam; Cut-offs; Indicators; Valves; Scale; Condensers, &c.; Management of Engines and Boilers at Sea, &c."

In addition to the merit of "literary" clearness already mentioned, the above work is also remarkable for that care in printing and illustration which adds so much to the satisfaction experienced in reading a good book. It is printed on tinted paper, in clear, well sized type, with many illustrations, and is bound in a style which, by reason of

its combined simplicity and elegant finish, would make it "at home" on a parlor table as well as in an engineer's berth. H. M.

Quartz Operator's Hand-book. WHEELER & RANDALL. San Francisco: 1865. 18 mo. pp. 130.

An excellent little book upon a subject which is every day demanding more attention from our citizens. The name itself states the intentions of the work, and these intentions are well fulfilled in the text. The explanations are clear in language and precise in statement, and free from the verbosity which disfigures so many similar works. If called upon to censure, we might say that the book would be better for more method in its arrangement of subjects. The statements, so far as we took them in a cursory glance through the book, are unusually accurate for such a manual, and finally, the neatness and clearness of its typography is a credit to the city in which it is printed.

National Lyrics. By JOHN G. WHITTIER. *Songs for all Seasons.* By ALFRED TENNYSON. *Lyrics of Life.* By ROBT. BROWNING. Boston: Ticknor & Fields, 1865.

A criticism on such books as these would not be in place on our pages, and we notice them only to express our conviction of the usefulness of such publications, even in the most utilitarian point of view. After work, play. Nothing conduces more to clear thinking and to the power of energetic and continuous unity, than the total unbending of the mind at least once in the twenty-four hours; and this relaxation is more thoroughly and more comfortably procured by changing the direction of the thoughts than by ceasing entirely to think. A state of idleness is painful and distasteful to every energetic and faithful man, but a total change in the character of his ideas is even more useful than corresponding alterations of his food; hence, every thing which nurses the feelings, which exalts to the contemplation of the beautiful, and stirs up our sympathies with our fellow men, is, in its place, important, and even more so to the artizan and the manufacturer whose attention during business hours is necessarily totally absorbed in the hard truths of nature, than by the artist, a man of leisure, from whose mind they may never be entirely absent. We look, therefore, with pride and satisfaction on the propensity of our American mechanic to read what are called books of amusement, and especially we recommend poetry to him as a means of elevating his feelings. We are, therefore, doubly glad to see such a work as that of Mr. Whittier's put within the reach of every one's pocket, for it contains matter for American thought and American sympathies, and is, in so far, very superior to the lackadaisical ballads which come to us from the Old World.

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CIVIL ENGINEERING.

Railway Over the Mont Cenis.

From the Civil Engineer and Architect's Journal, August, 1865.

A series of official trials on the proposed railway over Mont Cenis, to be used during the construction of the celebrated tunnel through the mountain, has just been concluded. Captain Tyler, R.E., was commissioned by the English government to be present at these trials, and to report thereon, which he has recently done. The experiments were to be made with the loads, and at the rate of speed required to carry out the programme of the projectors for trains crossing the mountain between Susa and St. Michel, carrying fifty passengers, their baggage, and the mail, and performing the distance in 4½ hours. But throughout the trials the stipulated speed was exceeded. The portion of the high road over the Cenis that has been granted for the the railway line is the outside skirting; that is to say, the edge of the precipice. Measures had to be taken to obviate risk, and persons who have well examined and repeatedly traveled over the portion of the line already constructed, have expressed a most decided opinion in favor of its safety. Until the contractors had thoroughly satisfied themselves of the possibility of securing complete safety, it would have been folly for them to embark at all in the undertaking.

There is a break of 47·6 English miles, from St. Michel to Susa, in the railway communication between France and Italy by the Mont Cenis route, and the contract time allowed for traveling by diligence between those two places is 9 hours in summer, and 10½ in winter. The

passage of the mountain, which may be said to commence on the French side at Lanslebourg, is by an excellent road, 9 to 10 metres (say 30 to 32 feet) in width, and on an average gradient of 1 in 13; but the traffic is much impeded during the winter season by snow; and considerable risk is incurred in some states of the weather from the fall of avalanches, and from the difficulty of guiding the heavy diligences over ice and snow in the descent. During portions of the winter, indeed, the service is performed by sledges, and the time occupied by the journey is uncertain, depending on the state of the weather.

To save time, and to obviate the inconveniences of this passage, the Grand Tunnel of the Alps is in course of construction between Modane and Bardonèche for a length of 12,220 metres (7·593 miles). In this tunnel, headings have been driven for 2011 metres from Modane, and 2700 metres from Bardonèche, leaving 7509 metres (about $4\frac{2}{3}$ English miles) to be pierced. The boring machines in this tunnel, ingeniously contrived by Messrs. Sommeiller, Grandis & Grattoni, are worked by air, which is compressed to five atmospheres by water-wheels in the valley below, and about a mile and a half distant from them, and the headings are formed by successive explosions of gunpowder, in the usual way, as soon as the holes, about 3 feet deep, have been formed (and tamped) in the rock.

It is stated that 400 horse power has been exerted by five of these water-wheels at Modane, to provide 27 horse power working nine jumpers at the face of the excavation, and to afford indifferent ventilation (except at the spot where the boring machine is at work) to the interior, while £8000, or more, has been recently expended in constructing cylindrical boiler-shaped reservoirs for compressed air, to contain a supply sufficient for about half a day's working in the tunnel. These reservoirs are filled during the intervals when the boring machines are not at work.

Captain Tyler states that, "looking to the rate of progress which has hitherto been effected, and the probable nature of the rocks, it cannot be expected, without taking into account any extra difficulties of ventilation, or from water, which may be encountered, that this tunnel can be completed in less than from seven to eight years. There are other works also on the permanent railway, as at present projected, including other tunnels, which will occupy many years in construction."

Under these circumstances, Mr. J. B. Fell has proposed to the French and Italian governments, on behalf of Messrs. Brassey & Co., to construct a railway from St. Michel, over the Mont Cenis, to Susa, to be used pending the completion of the grand tunnel, and the permanent railway to be connected with it. Mr. Fell has asked for no pecuniary aid from either of those governments, as the association with which he is connected are confident of making profit out of the work, besides reimbursing themselves for their outlay of capital and interest, by the time that the tunnel is completed.

But the gradients contemplated were such as could not be surmounted by any locomotive engine working with a load, on the ordinary system of trusting to its weight for adhesion between its wheels

and the rails; and it was considered that the best method of obtaining extra adhesion would be by the revival of a system long since patented, but never carried out, of adding a third rail between the ordinary bearing rails, to be acted upon by horizontal driving wheels on the engine. A locomotive engine was accordingly constructed, from one of a number of designs which have been patented and described by Mr. Fell, with two pairs of horizontal, as well as two pairs of vertical driving wheels, and an experimental line 800 yards long was laid down in Derbyshire, on the Cromford and High Peak Railway, with the permission and assistance of the London and North Western Railway Company. The gauge was 3′ 7⅝″, and there were 180 yards of straight line on a gradient of 1 in 13·5, and 150 yards of curves, with a radii of 2½ and 3½ chains, on a gradient of 1 in 12. The third rail upon this line, to be clipped between the horizontal driving wheels of the engine, was laid on its side 7½ inches above the other rails. In the course of a series of experiments, carried on from September, 1863, to February, 1864, the first engine that was constructed, working up to a pressure of 120 lbs. to the square inch, never failed, as I am informed, to take a load of 24 tons up the above inclines and around the above curves, and its maximum load was 30 tons. The outer cylinders, working on the four vertical wheels, which carried 16 tons when the engine was fully loaded, could only draw up, besides the weight of the engine, a loaded wagon weighing 7 tons; while the inside cylinders, acting on the horizontal wheels, which pressed with 12 tons against the middle rail, enabled the engine to take up 24 tons on the same day, and under the same conditions. The inside cylinders alone were able to carry up the engine itself round the curves, and they exhibited the power of taking up altogether 17 tons, as against 23 tons for the outside cylinders, which were nearly in proportion to the pressure and weight upon the horizontal and vertical wheels respectively. The experiments on the High Peak Railway were so successful that it was determined, with the permission of, and for the satisfaction of, the French government, to repeat them on a larger scale on the slopes of the Mont Cenis; the Italian government having undertaken to grant a concession to the promoters for the south side of the mountain, conditionally on a concession being obtained from the French government for the other side; and the French government having promised their concession, after some correspondence and delay; on the condition of the practicability of the scheme being demonstrated.

The experimental line which has now been constructed on the Mont Cenis, is situated between Lanslebourg and the summit, commencing at an elevation of 1622 metres, and terminating at an elevation of 1773 metres (or 5815 English feet) above the sea. It is nearly two kilometres, or a mile and a quarter, in length, and rises for the whole of that distance with a mean gradient of 1 in 13, the maximum gradient being 1 in 12. It passes round a sharp corner, joining two of the zigzags of ascent, on a curve of 40 metres, or about 2 chains' radius, and, except at this point, it is laid on the outside of the road, occupying

a width of $3\frac{1}{2}$ to 4 metres, and leaving 5 metres and upwards clear for the road traffic.

The portion of the road which remains appears to be quite sufficient for the circulation of the existing traffic. The diligences and other conveyances traverse the mountain with no more difficulty than before, and with the additional protection of the railway fence between the road and the precipice. Less inconvenience has been experienced than was anticipated from working the locomotive engines so near to the public road; and as the same horses and mules are, for the most part, employed upon the mountain, they will become more and more accustomed to the noise of the engines and trains. During three months of working, no accident appears to have occurred. The traffic on the road will, of course, be comparatively inconsiderable after the opening of the railway, and there can be no doubt that the portion of the road remaining for it will then be amply sufficient for all purposes.

This experimental line has been purposely constructed on the most difficult portion of the road on which it is proposed to leave the railway without covering, and it was well tested as to the difficulties arising from snow during very severe weather, in the early part of the present year. The result could hardly have been expected. Better adhesion was obtained on the rails in the winter than can be looked for in the summer season. The snow, when removed from the rails in hard weather, left them dry and in good condition, while the peculiar dust of the roads, especially when mixed with water, renders them comparatively greasy or slippery.

This line is laid on a gauge of 1·10 metre, (or $3' \, 7\frac{5}{8}''$,) with rails borrowed from the Victor Emanuel Railway Company, of the I section, weighing about 75 lbs. to the lineal yard. The bearing rails are fished at the joints, and are supported in cast iron chairs, which are spiked, in the ordinary way, to transverse wooden sleepers, 3 feet apart. The only peculiarity (beside the steep gradients and sharp curves) consists in the addition of a middle rail of the same section, which is led on its side between the other two, and at an elevation (to its centre) of $7\frac{1}{2}$ inches above them. This rail is supported partly on cast and partly on wrought iron chairs, weighing 20 lbs. each at the joints, and 16 lbs. each in the intermediate spaces.

These chairs are now 6 feet apart on the straight line, and from 2 to 3 feet apart on the curves, and the joints of the middle rails are not yet fished. But it is intended to add fish plates immediately to the joints of these rails, and, when the line is laid permanently, to place the chairs 3 feet apart on the straight line, and 1 foot 6 inches apart on the curves, besides securing them to the longitudinal timbers on which they rest by means of through bolts. The longitudinal timbers are 8 inches deep by 12 inches wide, and they are spiked to the transverse sleepers. They will be more securely affixed to them in the permanent road.

The above rails are unfavorable for use as intermediate rails, because the horizontal driving wheels of the engines only bite upon projecting parts of the squared edges of their section; and they are not of

the best quality for affording adhesion; but it was an advantage to be able to procure them in the country, and it may be considered that the rails which will be specially supplied for the permanent line will, at all events, not be less efficacious.

The whole line from St. Michel to Susa will be on average gradients (supposing the culminating point in the middle) of 1 in 25·6. The steepest gradient will be 1 in 12, and a middle rail will be added to the permanent way for all gradients steeper than 1 in 25.

Out of 1960 metres on the experimental line, there are 850 metres of curves, in 450 of which the radius of curvature varies from 84 to 40 metres, while in the remaining 400, the radius measures 100 or more metres. The proportion of curves on the whole line between St. Michel and Susa will be much less; and Mr. Fell proposes, by a happy idea, to modify the gradients on the sharper curves, and to make the gradients on the straight portions of the line contiguous to them more abrupt, though not steeper than 1 in 12. The extra resistance that would otherwise be afforded, in consequence of the friction of the engine and vehicles in passing round the worst curves, will thus be partly avoided, and the tractional resistances over the different parts of the line will be more nearly balanced, because the sharpest curves and the steepest gradient will not occur any where at the same point.

There will be ten level crossings of the road, and six of them on gradients steeper than 1 in 25. The middle rail will be left out at the point of crossing in some of these cases, and will probably be passed by ramps (for animals and vehicles using the road) in others.

The covered ways on different parts of the mountain will extend, altogether, over from 12 to 15 kilometres, ($7\frac{1}{2}$ to $9\frac{1}{3}$ English miles,) but the latter amount has been provided for. They will be of three descriptions, comprising a wooden roof and sides for, say, 5 kilometres, to keep off light falling snow; a structure of wood, strengthened by iron, for 7 kilometres, as a protection where the snow drifts in deep masses; and a strong masonry arch, for 3 kilometres, in passing the various runs of the avalanches.

There are no exact records of the amount of snow that falls upon the Mont Cenis, but it appears that the cost of clearing it sufficiently to keep the road open for traffic is at present about 12,000 francs annually, as against 31,900 francs on the average for the St. Gothard. The cost of clearing it for the use of the railway, and the difficulties which it would occasion to railway traffic would be small, compared with its present cost and the difficulties of the road traffic, for several reasons. In the first place, the railway would be under cover in those parts of the mountain where the snow would occasion the greatest risk and inconvenience. (2.) The railway would generally, when not under cover, be on the outer side of the road. (3.) The locomotive engines would be available for working the snow ploughs, when fresh falls of snow necessitated their use. The cost of clearing snow from the railway on the Semmering incline is given at 200 francs per kilometre per annum.

The two locomotive engines now on the Mont Cenis have been de-

signed with a special regard for three objects. 1. To develope a maximum of power with a minimum of weight, so as to leave as great a surplus as possible for conveying traffic on steep gradients. 2. To afford extra adhesion, independently of their weight, by means of horizontal wheels pressed by springs behind the axle boxes against an intermediate rail. 3. To work at moderate speeds and round very sharp curves. No. 1 engine weighs 14 tons 10 cwt. when loaded with coke and water. Its boiler is 7′ 9½″ long, and 2′ 9″ in diameter, and it contains 100 tubes of 1½″ external diameter. It has a heating surface of 420 square feet, and a grate area of 6′ 6″. It is provided with four cylinders, two outside cylinders 11¾″ in diameter, with a stroke of 18″, for working four coupled vertical wheels 2′ 3″ in diameter, with a wheel base 5′ 3″, and the two inside cylinders 11″ in diameter, with a stroke of 10 inches, for working four horizontal coupled wheels 1′ 4″ in diameter, with a wheel base of 1′ 7″. It has now a pressure of 16 tons on the horizontal wheels, 4 tons more than was at first applied to them, and about the same weight as is carried from the weight of the engine of the vertical wheels. Guide wheels have also been added to the trailing end of the engine to act upon the middle rail.

This engine labors under serious disadvantages, inasmuch as its machinery is too much crowded together for convenience in readjustment or repair; its boiler power is not sufficient for working the fast traffic of the Mont Cenis, and the oil from its machinery falls upon the horizontal wheels, and deprives them, to some extent, of their power of adhesion. But it has, nevertheless, gone far to prove the principle which it was to test or establish; and it is, considering the novelty of the undertaking, a surprising success.

In the course of two days, I took six trips with this engine, up and down the experimental line, carrying each time a load of 16 tons, in three wagons, including the weight of the wagons, and it performed in the ascent 1800 metres in 8⅛ minutes, with a loss of 14 lbs. of steam, and of 5½ inches of water in the gauge glass, at steam pressures varying between 92 and 125 lbs. to the square inch in the boiler as the average of all those experiments.

The speed attained was in every case greater than that which it is proposed to run with the same load with these express trains; and the average speed as above given was at the rate of 13⅓ kilometres (or 8⅓ English miles) per hour, instead of 12 kilometres (or 7½ English miles) per hour which is the highest running speed allowed in the programme given to the French government for this part of the line. The weather was fine and calm, and the bearing rails were in first-rate order, but the middle rail as well as the horizontal wheels were oily, and therefore in a condition very unfavorable for good adhesion.

The following calculation shows the average work which was performed by No. 1 engine in the course of these experiments. Omitting in the first instance the extra resistance from sharp curves and neglecting that from the atmosphere, we have the

Resistance from gravity, ...	$= \frac{32 \times 2240}{13} =$	5,514
Friction of bearing engine (outside cylinders), . .	$= 16 \times 20 =$	320
Friction of pressure engine (inside cylinders), . .	$= 16 \times 20 =$	320
Friction of train, ...	$= 16 \times 10 =$	160
And the tractive force exerted, ...		= 6,314 lbs.

1800 metres $\div 8\frac{1}{8}$ minutes $= 5{,}906$ feet $\div 8\frac{1}{8}$ minutes $= 727$ ft. per minute.

And $\frac{6{,}314 \text{ lbs.} \times 727 \text{ ft. per minute}}{33{,}000 \text{ ft. pounds per minute}}$, ... = 139 H.P.,

as against the same load at 12 kilometres per hour, . . = 125 H.P.
Adding 10 per cent. for extra resistance on sharp curves in each case,
139 + 10 per cent. = 153 horse power at 1800 metres in $8\frac{1}{8}$ minutes.
125 + 10 " = 137·5 " 1800 " 9 "

15·5 excess of horse power above what was required.

The consumption of fuel during these experiments is hardly worth recording, because it was impossible to distinguish between what was burnt while the engine was standing, and that which directly contributed to the power exerted. But the engine having been under steam about 3 hours the first day and $3\frac{1}{2}$ hours on the second day, there was consumed altogether, as nearly as I could ascertain, 583 lbs. and 653 lbs. of mixed fuel on those days respectively. Of the above time, about 97 or 98 minutes were occupied in running 15 miles during the experiments up and down the line on both days.

This engine has run upwards of 100 miles altogether in ballasting and conveying materials upon the experimental line, carrying loads of from 16 to 20 tons, without accident or difficulty.

No. 2 engine, intended specially for working the traffic of the Mont Cenis, is partly of steel. Its net weight is 13 tons, and its greatest weight, when fully loaded with fuel and water, 16 tons 17 cwt., giving a mean weight of 16 tons, which will be brought up, when certain parts have been strengthened as contemplated, to a maximum weight of 17 tons 2 cwt., and a mean weight of 16 tons 4 cwt. The extra machinery for the horizontal wheels weighs, however, only 2 tons 13 cwt.

The boiler is 8′ $4\frac{1}{2}$″ long, and 3′ 2″ in diameter, and contains 158 tubes of $1\frac{1}{2}$″ external diameter. The fire-box and tubes contain altogether 600 superficial feet of heating surface, and there are ten feet of fire-grate area. There are only two cylinders, with a diameter of 15″ and a stroke of 16″, which work both the four coupled horizontal, and the four coupled vertical wheels, which are all 27″ in diameter. The wheel base of the vertical wheels is 6′ 10″, and that of the horizontal wheels 2′ 4″. The maximum pressure in the boiler is 120 lbs., and the effective pressure on the piston is 75 lbs. to the square inch.

Besides possessing a greater amount of boiler power, this engine travels more steadily than No. 1; its machinery is more easily attended to, and the pressure upon its horizontal wheels can be regulated by the engine driver at pleasure from the foot plate. This pressure is applied through an iron rod connected by means of right and left handed screws with a beam on each side of the middle rail, and these beams act upon

volute springs which press the horizontal wheels against that rail. The pressure employed during the experiments was $2\frac{1}{2}$ tons on each horizontal wheel, or 10 tons altogether; but the pressure actually provided for, and which may, when necessary, be employed, is 6 tons upon each, or 24 tons upon the four horizontal wheels.

The vertical wheels are worked indirectly by piston rods from the front, and the horizontal wheels directly by piston rods from the back of the cylinders. The motions connected with the horizontal wheels appeared to be working perfectly well; but unfortunately some of the parts in front of the cylinder connected with the vertical wheels required strengthening, and it was not desirable, for fear of injury that would cause further delay, to test the engine much or heavily while I was upon the mountain, or until the new parts, which are under construction, had been received from England. I was able, however, to take it up 1800 metres on the experimental line with the same load as before, of 16 tons in three wagons in $6\frac{1}{4}$ minutes, or at a speed of $17\frac{1}{3}$ kilometres per hour, as against 12 kilometres per hour which it is proposed to run with the express trains. The steam pressure in the boiler fell from 112 to $102\frac{1}{2}$, and 3 inches of water were lost in the gauge glass, the feed having been turned on during the later period only of this experiment. No. 2 engine (whose frictional resistance is 120 lbs. less than No. 1 engine, when only 10 tons of pressure are employed on the horizontal wheels) exerted, in this instance, omitting the extra resistance from curves, 177 horse power, or adding 10 per cent. for the resistance from curves, 195 horse power, or more than 12 horse power to each ton of its own weight, and nearly 60 horse power in excess of what was required to take the same load up the same gradients and curves at 12 kilometres per hour, as proposed in the programme.

Allowing 4 feet of heating surface to each horse power, this engine ought to be capable of maintaining 150 horse power, or 45 horse power less than it exerted for a comparatively short distance in the above experiments, but considerably more than it will be necessary to exert to carry out the programme. And, indeed, a light train carrying despatches and 50 passengers, and drawn by one engine, would perform the journey without difficulty in four hours, instead of four hours and a half, from St. Michel to Susa.

I observed on the following day, that 40 lbs. of steam pressure in the boiler, or one-third of the maximum pressure employed, was sufficient to move the engine alone up a gradient of 1 in $12\frac{1}{2}$; and the friction of carriages or wagons being proportionately much less than that of an engine, the same engine ought, *a fortiori*, to be able to move a gross load of three times its own weight, or 48 tons, at its greatest working pressure, up the same gradient.

The only passenger carriage that has yet been constructed is 6′ 4″ wide, by 12 feet long, by 6 feet high inside. It has a passage down the middle, and six seats on each side, on which passengers sit facing one another. The wheels are 2′ 3″ in diameter, and it is intended that all carriage and wagon wheels shall run loose on one side of the axle. Every vehicle will be provided with a break of the ordi-

nary description, and a large proportion also with breaks acting on the middle rail.

The road traffic between St. Michel and Susa appears from the returns of the Victor Emanuel Railway to show an average increase of rather more than 10 per cent. per annum during the last four years. Estimating the traffic to increase in the same ratio only after the opening of the railway, the total revenue in seven years, from 1867 to 1873, would be upwards of 27,000,000 francs ; and it is considered that such a revenue would leave. at the end of that time, a clear profit of several millions of francs, after deducting all charges, and after paying interest upon, and paying off, the total bond and share capital of 8,000,000 francs. The value of the railway and rolling stock would also be, at the end of that time, to the credit of the company. But it cannot be doubted that the passenger traffic would increase in a much greater ratio after the opening of the railway, in consequence of the great saving of time, and the greater comfort and convenience in the passage of the mountain ; or that there would be, not only an increase in the goods traffic, but also a prospect of developing a traffic of cheaper goods and minerals which do not, as yet, pass over the mountain. And the projectors have, further, a reasonable hope of carrying the Indian mail, on the ground that they will be able to save 38 hours of time in its transmission between England and Egypt.

To provide for the carriage of 132 passengers and 88 tons of goods daily, they propose to run three trains each way, namely, one train carrying 40 passengers and their luggage, weighing, exclusive of the engine, 16 tons, and traveling at a mean speed of 18 kilometres per hour for the 77 kilometres between St. Michel and Susa ; a second train carrying 26 passengers and 20 tons of goods, and weighing 40 tons, at an average speed of 12 to 14 kilometres per hour ; and a third train, carrying 24 tons of goods, and weighing 48 tons, at an average speed of 10 kilometres per hour. The first of these trains they propose to take up the mountain by one engine, and the second and third by two engines each.

The relative distances by the Mont Cenis route from Paris to Turin and Genoa, and the route by Marseilles to those places, may be thus stated: In proceeding from Paris the two routes diverge from the common point of Macon, and the distances are

	By Marseilles, English Miles.	By Mont Cenis, English Miles.
Macon to Genoa, ...	559	326
Macon to Turin, ...	659	226

showing a saving in favor of the Mont Cenis route of 233 miles to Genoa and 443 to Turin.

The time that would be occupied in the journey between this country and Egypt, *via* Paris, may be estimated for the route by Marseilles, and the route by Mont Cenis and Brindisi (the Italian railways having recently been opened for traffic to that port) respectively as follows:

For the Marseilles route:

Paris to Marseilles, 864 kilometres, at 54 per hour,				16 hours.
Marseilles to Alexandria, 1460 nautical miles, at 10 per hour, with 6 hours' delay at Malta,				152 "
Total,				168 "

For the Brindisi route, by Mont Cenis and Brindisi:

Paris to Macon,	441 kilometres at	54	per hour,	$8\frac{1}{4}$ hours.
Macon to St. Michel,	237 "	40	"	6 "
St. Michel to Susa,	77 "	18	"	$4\frac{1}{2}$ "
Susa to Brindisi,	1159 "	40	"	29 "
Brindisi to Alexandria,	822 nautical miles,	10	"	$82\frac{1}{4}$ "
Total,				130 "

showing a saving in favor of the Mont Cenis and Brindisi route of 38 hours. This would be of importance in facilitating the communication between this country and India, and in the transmission of the Indian mail, though it is to be observed that there would necessarily be a change of vehicles at St. Michel and Susa.

The results of this experiment are of great importance to the future of railway construction in mountainous countries, as will be seen from the following observations:

Whenever it becomes necessary to cross a chain of mountains by a line of railway, the question arises as to whether it will be more economical to pass over the summit, or to make a tunnel of greater or less length. The cost of construction, and of working the estimated traffic, being duly considered, it is necessary to determine what elevation should be reached, and what length, if any, of tunnel should be formed, according to the circumstances of each case, and the most important element in the calculation is the limit up to which steep gradients may be safely and economically worked.

Mr. Fell has shown practically that gradients of 1 in 12 to 1 in 15 may, by a system of horizontal driving wheels acting upon a middle rail, be substituted for 1 in 25 to 1 in 30, which have hitherto been practicable, and that sharper curves may also by this system be more safely worked. He has proved, in other words, that a railway may be constructed over a given summit of half the length that would otherwise have been necessary, and at less than two-thirds of the cost; because, although the permanent way would be more expensive, averaging, say, £3000 instead of £1800 to £2000 a mile, yet, by the adoption of steeper gradients and sharper curves at critical points, cuttings or embankments may be reduced or avoided, and the works generally be more cheaply laid out. And the cost of working and maintenance would, considering the same elevation to be reached, be cheapened, as well as the cost of construction. There would be half the length of line to maintain, and the speed of the trains would be reduced. Only half the speed would, indeed, be required to reach the summit in the same time, and the same (gross) loads might be taken up by the same expenditure of power at that speed so reduced to one-half, while the adhesion of the locomotive engines being doubled with the addition of no more than a sixth to their weight, an important saving would thus

be effected in the dead weights of the trains. The cost of traction, which must in taking a given (gross) load to a given height be nearly the same, would not increase so much in consequence of the saving of dead weight thus effected; and other expenses would decrease to some extent in proportion to the wear and tear and resistances incidental to a higher, but avoided at a lower, velocity.

A summit line may for these reasons be made with greater facility in less time and to greater advantage than heretofore, and it will be interesting, taking the Mont Cenis as an example, to compare the cost of the tunnel line now in course of construction under that mountain with a permanent line, which might be made over it. The comparison is not made here with a view to that particular case, because it may now be taken for granted that the permanent tunnel line will be completed within a certain number of years, and because the summit line projected by Messrs. Brassey & Co. is only put forward as a temporary line, to be used pending the opening of the permanent line from St. Michel to Susa, but as being important with reference to other mountain passes in the Alps and elsewhere.

The temporary line is estimated (by Mr. Brunlees, C.E., to cost 8,000,000 francs, or £320,000, or about £6720 per mile, whereas the tunnel line will probably cost, including interest at 6 per cent. during construction, 135,000,000 of francs, or £5,400,000, or £128,500 per mile, the latter being 68 kilometres (42 miles) in length, with a maximum gradient of 1 in 28, and a gradient through half of the grand tunnel of 1 in $35\frac{1}{2}$, and an average gradient for the whole of 1 in 46; and the former being 77 kilometres (about 48 miles) in length, with a maximum gradient of 1 in 12, and an extra elevation of 2520 feet, and the time occupied between St. Michel and Susa would, including stoppages, be about 3 hours by the tunnel and $4\frac{1}{2}$ hours by the summit.

The cost of a permanent and independent summit line with a wider gauge and better curves, may be taken at £20,000 a mile, or nearly three times as much as the above temporary line, and the extra cost of working over a super-elevation of 2520 feet, based upon a traffic ten times as great as that which is carried at present over the Mont Cenis, and upon the average cost of traction (0·25 of a franc or $2\frac{1}{2}d.$ per horse power per hour) upon the Semmering and Giovi inclines, capitalized at 6 per cent., at £13,000 per mile. These two sums added together amount to £33,000 per mile, or rather more than one-fourth of £128,500 per mile set down above for the tunnel line.

This estimate would, of course, be materially modified by local circumstances, but it is as good an illustration as can be given at present of the advantages that may be derived, in cases in which stationary engines and inclines worked by ropes are not appropriate, from constructing railways on steeper gradients than have hitherto been considered practicable, in the manner which Mr. Fell has now shown to be available.

As the results of his observations and experiments, Captain Tyler reports in conclusion, that this scheme for crossing the Mont Cenis is, in his opinion, practicable, both mechanically and commercially, and

that the passage of the mountain may thus be effected, not only with greater speed, certainty, and convenience, but also with greater safety than under the present arrangements. Few would, in the first instance, either contemplate or witness experiments upon such steep gradients, and round such sharp curves on the mountain side, without a feeling that much extra risk must be incurred, and that the consequences of a fractured coupling, or a broken tire, or a vehicle leaving the rails, would on such a line be considerably aggravated.

But there is an element of safety in this system of locomotive working which no other railway possesses. The middle rail not only serves to enable the engine to surmount and to draw its train up these gradients, but it also affords a means of employing any required amount of extra break power for checking the speed, or for stopping any detached vehicles during the descent; and it further acts, by the use of horizontal guiding wheels on the different vehicles, as a most perfect safeguard, to prevent engines, carriages, or wagons from leaving the rails, in consequence either of defects in the bearing rails or of failure in any part of the rolling stock. The safest portions of the proposed railway ought, indeed, under proper management, to be those on which, the gradients being steeper than 1 in 25, the middle rail will be employed.

There is no difficulty in so applying and securing that middle rail, and making it virtually one continuous bar, as to preclude the possibility of accident from its weakness or from the failure of its fastenings, and the only question to my mind is, whether it would not be desirable still further to extend its application to gradients less steep than 1 in 25. It would apparently be advantageous to do so, not only for the sake of obtaining increased adhesion with less proportional weight, and, therefore, economical traction, but also with a view to greater security, especially on curved portions of the line.

After going with Mr. Fell through the different calculations and considerations which are involved in the undertaking, Captain Tyler finds that he has, during three years of labor, treated them with the utmost care and caution, and has no doubt of his being able (if Mr. Fell obtains, as he hopes to do in the course of a few weeks, the necessary authority from the French government) to carry it forward to a successful issue. It is anticipated that in the course of the summer of 1866, in time for the autumnal stream of travelers into Italy, Mont Cenis will be traversed by rail in $4\frac{1}{2}$ hours, or even less, from St. Michel to Susa, now a tedious diligence journey, on wheels or sledge, according to season, lasting more than double that time.

On Marine Engines from 1851 *to the Present Time.*

By N. P. Burgh, Esq., Engineer.

From the Journal of the Society of Arts, No. 643.

(Continued from page 242.)

Having alluded to the principal working details, I will now lay before you a description of the mode of condensation—past and present. It

is well known that the principle of condensation is to convert the steam into its original state. The contact of the cool fluid, in the shape of water, accomplishes this in the ordinary condenser, and cooling surfaces in the surface condenser.

In the days of the introduction of side-lever engines, the arrangement of the condenser and air pump was faulty; in some cases the foot-valves were almost inaccessible. Not many years ago, being on board a steamship fitted with old side-lever engines, which were then undergoing repair, I noticed a rope and block-tackle over near the condenser. On inquiring of the engineer how he progressed, the answer was, "I am just going to sling one of the men with this tackle by the heels, to inspect the foot-valves; and that," said he, "is no foolish job." On further examining the engines, I found that an upside down attitude was required, and indeed the only one allowed for the inspection of the valves in question. Happily now, however, such an inconvenient arrangement is of rare occurrence. We also find the side-lever engine is being superseded by that of the oscillating type.

The arrangement of the ordinary condenser and air pump for oscillating paddle engines is generally as follows: The condenser is situated between and below the trunnions of the two cylinders; the air pumps are at an angle, with trunks and connecting rods of the ordinary kind; the foot-valves are at the bottom of the barrel of the pump; the piston has valves in it, and the discharge valve, when not at the the top of the pump barrel, is at its side. Now, the principal defects in this arrangement are in the position of the valve and condenser. When the foot-valves are directly underneath the pump's piston, it is obvious that an almost entire disconnexion must be made to inspect them. Also, in the case of the piston valves requiring inspection, the pump cover must be removed, and to attain this the gland packing has to be slackened, and the connecting rod disengaged. Now, to avoid these evils, doors might be introduced, but with these disadvantages—increased height or length of the air pump passages, and a body of water always above and below the piston, which is undoubtedly what any right-thinking engineer would disapprove of, it being clearly understood that an air pump will produce a better vacuum when the piston thoroughly discharges the contents between the foot and delivery valves at each stroke.

Having thus pointed out the existing evils of the ordinary arrangement, it will not be deemed out of place to introduce a remedy. The condenser at the side of or below the pump is in one of the worst positions that can be conceived; the idea of allowing the condensed steam to fall only to be raised again, seems, on consideration, to be foreign to the ideas of our talented engineers. It is well known that, in ordinary arrangements, the condenser is always in the position alluded to; steam, even of a low pressure, is larger in volume, but not as dense and heavy as water; it is also more elastic, hence it will more readily ascend. This, then, being clearly understood, it is not unwise or impracticable to assume, that if the condenser were on the top of the air pump, instead of at its side or bottom, a better vacuum would be main-

tained. I beg to offer a description of an arrangement of condenser and position of the valves, both for correct action and accessibility. It will be understood that the condenser in this case is over the air pump; the suction valves are inverted, consequently the weight of the water assists the action of the piston in causing a vacuum. The exhaust steam from the cylinders rushes up the exhaust pipe, and enters on the top of the condenser. The water in the air pump is discharged through the delivery valve, at the top of the pump, and from thence through the delivery valve at the ship's side. A door is secured opposite the delivery valve, and doors are provided on each side below the bottom of the condenser, for the double purpose of inspecting the suction valves and the air pump piston.

This arrangement of condenser and air pump will occupy as little room as those of the ordinary kind, with the advantage of accessibility to all the working parts without disarrangement. It may be argued that the stuffing box, being in a recess when used for guides, would be troublesome to keep tight or repack, but if oil be always kept in the recess, so as to entirely cover the gland, it would tend to lessen the liability of leakage; the nuts of the gland and bolts could be adjusted by a box spanner, or the bolts prolonged to the top of the condenser. In cases where the depth of the ship would admit, the recess could be dispensed with; trunks are not proposed for this arrangement, as their diameters would be necessarily increased, owing to the length required to pass through the condenser, unless a recess were resorted to, as now proposed.

The next portion of the subject now before us is the ordinary condenser for screw engines. The action of the air pump in this case is usually horizontal; consequently the valves are at right angles to the pump. To describe each arrangement of condenser and air pump that have come under the writer's notice would occupy too much time; consequently a brief mention of two or three examples on this occasion will be deemed sufficient. For direct acting and trunk engines, with the cylinders secured together, or side by side, the condensers were between and, in some instances, in front or at the sides of the air pump. The foot and discharge valves were directly over each other, the former under the pump at each end, the condensed water or steam being drawn through the foot valves and forced through those above. In another instance the foot and delivery valves were extended the entire length of the air pump and passages, the position of the valves over and under being as before, and the condenser being between the air pumps. For return connecting rod engines, the condenser and air pumps are subject to great disadvantages. In order to obtain a passably good arrangement, and, at the same time, occupy a moderate space in proportion to those last mentioned, the condenser, &c., have to be shaped to suit the purpose required. It must be perfectly understood that when the piston rods are beyond the crank shaft (as in the examples now in question) there is a certain amount of space required for the piston rods and guides of the crosshead, or guide block, whichever may be used. It is also clear that accessibility to all the valves

without disarrangement should be attained. To illustrate these desiderata the following examples will be sufficient for the present purpose: In one instance the condenser is partially between the cylinders, and extending beyond the crank shaft; the air pumps are at the side of the condenser; the suction valves extend the length of the air pump; and the discharge valves are between each pump, the pump and the valves being beyond the crank shaft.

The next example is as follows: The condenser and its appendages are entirely beyond the crank shaft. The air pumps are at the extremity or sides, and near the bottom of the condenser. The foot and discharge valves extend the entire length, and are arranged over and under the pumps in the usual form. The guides for the piston rods are between the upper portion of the condenser and that of the discharge chamber.

Having disposed of the principal arrangements of air pumps and condensers as formerly constructed, allusion will now be made to those of recent improvement and practice. As before stated, a better vacuum can be attained when the condenser is over the air pump instead of at its side. For direct acting engines there are two arrangements specially worthy of notice. 1. The air pumps are worked by the steam pistons between the cranks as near as the base lines of the engine as the periphery of the circles will admit, the condenser being one chamber, directly over the air pumps. The suction valves are inverted in the bottom of the condenser so as to effectually drain the same. The discharge chamber extends the entire length on each side and back end of the condenser, the valves being nearly in the same line as those for the suction, but reverse in action. The next example is the same as the last principle, although different in arrangement. The air pumps are situated as in the last example, but the condensers are separate, one to each engine, over and on each side of the air pump. The suction valves are inverted in the bottom of each condenser to obtain the advantage before alluded to, the discharge chamber and valves being central or between each condenser, and directly over and between the air pumps. It may now be argued, that if the two examples last mentioned are perfect in action and arrangement, what is the cause of the diversity? The answer to this is, Diversity of idea. Engineers, as a rule, are averse to the act of copying from each other. No sentence grates more harshly on the ear of a scientific man than the words, "Where did you copy this?" or is more repugnant to his dignity.

Having referred to the improvements in the arrangement of condensers, &c., for direct acting engines, attention will now be given to those adopted for double piston rod engines. It must be borne in mind that for this class of engine the prolongation of the piston rods beyond the crank shaft greatly deteriorates the arrangement of the air pumps and condensers, in relation to the space occupied by those for single piston rod engines. In the examples now given, the air pumps are worked by the steam piston, and as near the base line as possible. The condensers are separately arranged outside the guides of the piston rods

of each engine; the suction valves are inverted above the top of the air pump, as in the last examples; the discharge chamber is between the air pumps and the valves, on the same level as those for the suction. It will thus be understood that both suction and delivery are at the side, over and extending the length of each air pump, instead of being directly over them, as in some cases.

The next example worthy of notice is arranged as follows: The condensers and their appendages are beyond or outside the guides of each engine, the air pumps deriving their motion as in the previous examples, and are as near the base line as possible, so situated as to clear the guides. Partially over and beyond the side of each air pump are the discharge valves, above which is the discharge chamber; over this, and at the side of the same, is the condenser with the suction valves inverted.

I will now allude to the system of condensation known as surface condensation. Mr. Hall, in days of yore, introduced the tubular arrangement with great advantage. Engineers at that time were slow in appreciating the then presumed gain, and it is only lately that we have seen the surface condenser universally adopted by the powers that be. To condense steam properly is undoubtedly to reduce it to its natural or original state. Now, in the ordinary condenser we bring water into actual contact with the steam to condense it. Surface condensers are to be recommended, particularly for one reason, viz: the production of distilled water for the feed of the boilers. The arrangement of the tubes in surface condensers entails practical difficulties as to the position most suitable, whether they be inserted transversely, perpendicularly, or longitudinally of the hull of the ship, renewal of the tubes being often required (sometimes while at sea) from corrosion.

The means adopted to render the connexion of the tubes in the plate air-tight are numerous. The usual mode now is—india rubber rings recessed in the plates encircling each tube—compression being obtained by a nut for perpendicular tubes, and by the vacuum in the condenser for those of horizontal positions; this is simple and efficacious, and at the same time economical. It must here be remarked, however, that compression of the india rubber by vacuum can only be attained when the steam is condensed by the external surface of the tubes or within the plates. The circulation of the water is either through or surrounding the tubes, and is produced by pumps with plunger piston or centrifugal action. The position of the piston pumps is horizontal, motion being derived either from the steam piston or piston rod. The centrifugal pump requires a separate engine, or spur gearing, &c., from the crank shaft to give the required velocity.

The values of the two arrangements now used for the condensation of the steam are about equal. In the case of the water surrounding the tubes, the steam passes through the same, and in the case of the steam surrounding the tubes the position of the water is reversed.

It is obvious that where internal condensation is effected, a great number of tubes are required, in relation to those of the external system—the inner surface of the tube being less than that of the outer,

The advantage gained by the steam entering the tubes may be said to be—access for cleaning without disarrangement. Injection, or ordinary condensers, are more generally used than those of the surface kind, on account of economy in the outlay of capital at the commencement.

The injection valves for ordinary condensers are generally of the solid or gridiron type, the latter to reduce the stroke to open and close. The pipe for the dispersion of the water is usually a tube, with apertures, of an elongated or circular form. An improvement has lately been made in these pipes, by contracting the area for one-half the length, thus equalizing the diffusion of the water throughout.

The next valve necessary for the condenser is the shifting valve, which is a single disk of gun metal, with a slight spiral spring at its back, or upper part. A screwed spindle is universally used to prevent the valve from rising, after the water and air in the condenser has been blown out previously to starting the engines. It might be deemed neglectful if I were not to make allusion to the bilge injection valve or cock, whichever may be used. This valve, as well known, is only required in cases of necessity, such as leakages, or disarrangement of the bilge or donkey pumps. I would beg to suggest that the bilge water should not be allowed to enter the condenser, on account of the generally impure state of the bilges. A valve and box might be arranged at the end of the air pump for this purpose.

The portions of the marine engine next for exemplification are the feed and bilge pumps. The position of these is so arranged that a free access can be obtained to the valves and surrounding parts without disarrangement. Some makers prefer to work the feed and bilge pumps in a line with each other, with one rod and plunger direct from the steam piston. Other firms secure the pumps side by side to the discharge water pipe of the condenser, each plunger being connected to the piston rods crosshead; this latter improvement is more general than the former. In the case of hollow plunger or trunk air pumps, those for the feed and bilge are on each side of the air pump, and secured by nuts or keys. Before terminating this portion of the subject, it will be well to add that the valves for the air, feed, and bilge pumps are now universally disks of india rubber, instead of the gun metal spindle valves.

It will have been observed that no allusion has yet been made to the arrangement of combined high and low pressure engines. For the purpose of comparison I will allude only to those arrangements in common use. The position of the low pressure cylinders is side by side, as for those of the ordinary kind; in some cases annular cylinders are used, viz: the high pressure cylinder within that for the low pressure. Another arrangement is the high pressure cylinder on the top of that for the low pressure. A third arrangement has the smaller cylinder at the back end of the larger. A fourth example consists of two high pressure cylinders in front of one for low pressure, the former acting as guides for the piston rod. The means adopted for imparting the motion of the piston to the cranks are of the ordinary arrangements

already described, with the exception of the necessary extra piston rods and stuffing boxes.

Having alluded to the different engines and their details, past and present, adapted for the single screw, I will now call attention to a notice of arrangement of engines as at present used for the twin or double screw system. It must here be mentioned that the class of engines now under notice have precisely the same duty to perform as those before described; consequently, if I pass over the major portion of the detail it is to avoid repetition.

The arrangement of the engines is usually separate for each screw. The type of engine generally adopted at present is direct acting with surface or injection condensers. Single piston rod engines seem to be more in favor than those of the double piston rod return action type, I presume on account of the simplicity of the former. The position of the arrangement in plan is side by side—port and starboard—instead of directly opposite each other; this is owing to the space required for the arrangement adopted, and the small beam of the veessel; but in some cases, engines are arranged opposite each other, with a great reduction of space compared to that of the side system. When the crank shaftings are connected, the steering principle is destroyed, and the twin screw system, so far as regards propulsion, is very little better than the single system.

There is not the least doubt that, as a mode of steerage, the twin system is correct, and for shallow drafts it is advantageous. To suppose the plan to be universally correct for large vessels requires, however, more practical evidence than I at present possess; but of this I am confident, that for small or large vessels, whether for commercial or war purposes, the twin screws, when driven separately, are invaluable for steering. The advantages for war ships are principally the facility for manœuvering when under an engagement. Let it be presumed that the enemy has aimed at a twin screw steamer; by a contrary action of the screws her position can be shifted instantaneously, and the intended evil postponed, if not averted.

I have come to the end of my brief description of the marine engine, and will now allude to the weight of material, cost of marine engines, and the relation of nominal to actual horse power, together with the consumption of fuel. The variation in the weight of marine engines is due to the design and arrangement as much as the material used. Double trunks may be said to be a fair example as to the average weight of marine screw engines. Return connecting rod engines are perhaps the heavier, in comparison to those of the single type, in relation to rods and guides. High and low pressure engines combined are the heaviest of any examples yet given. The materials comprising the different portions of the engines of the present day are of six kinds—first, cast iron, of which is formed the cylinders, pistons, valves, casings, main frames, guides, condensers, &c.; secondly, wrought iron, comprising cranks and shaft, piston and valve rods, links, levers, weigh shafts, bolts, nuts, &c.; thirdly, steel for springs, small pins, &c.; fourthly, gun metal for bearings, guide blocks, bushes, glands, nuts,

&c.; fifthly, copper, for pipes of all kinds required for steam and water; sixthly, india rubber, for valves packing, &c. For the present occasion, in reference to weight, I have selected twelve examples of marine screw engines, each varying in power and design. The examples of arrangement being in pairs, the result has been that 4·334 cwt. per nominal horse power may be taken as the average weight of material, exclusive of boilers, fittings, screw propellor, and alley-shafting. It may here be observed that each maker of marine engines in the present day differs in design and arrangement, consequently the weight of trunk engines by different makers would be unequal. The same may be said for single piston rod engines, as well as for double piston rod return connecting rod engines.

I now come to that portion of this subject which is the crowning question of all, and too often the cause of much controversy in political and commercial circles, viz: what is the cost? My opinion is, that it is perhaps the most difficult query to answer that could be put, and the only reason for its introduction is to preserve myself from presumed neglect in not noticing this important matter. To ascertain correctly which is the cheapest class of engine at present in use, is a problem much too difficult for me to solve; but I will, however, tender such information as I deem reliable.

The price of a marine engine depends entirely on the class of workmanship. Should a roughly-finished engine and boiler be required, with more painted than polished surfaces, the cost will be reduced in comparison to that of the more highly finished. The fittings also greatly regulate the outlay. Some companies pride themselves on this portion of display, others, again, look on it as an unnecessary expense; so, to draw a correct line of comparison would involve the amalgamation of the many ideas in order to give a fair evidence. I feel confident, however, that marine engines, with boilers and fittings complete, can be produced of certain classes, for £70 per horse power nominal, and the same can be reduced to £50 per horse power, each price, of course, being under certain conditions as to terms and workmanship.

Allusion must now be made to the power, &c., of marine engines. Nominal power is a term used particularly for commercial purposes. Each maker has his private rule, hence the difference in dimensions in engines of the same class and power. Actual horse power is defined by the indicator diagram, speed of piston, &c.; the ratio between the nominal and actual power is in some cases low, in others high. The writer has known instances where, the nominal power being 1·0, the actual was 6·0; and in others, nominal 1·0, actual 2·123; the average ratio at present is, nominal 1·0, actual 4·0 to 5·0. With reference to the consumption of fuel, there is a great difference in the evidence. Superheating and surface condensation are slowly making progress, and at the same time reducing the consumption of fuel in ratio to the amount of water evaporated or steam used. The average actual horse power expended per cubic foot of water evaporated is, water being 1·0, actual horse power 2·635 to 4·0, and doubtless in some cases more.

TWIN SCREW PROPULSION.—*Tabular Statement of Ships, Marine Engines, &c., constructed by Messrs. Dudgeon & Blackwell, since 1851 to the present date, supplied by the firm.*

Beam of Vessel.	Length.	Depth.	Tonnage	Immersion.	Nominal horse power.	Diameter of cylinder.	Length of stroke.	Kind of Condenser.	Diameter of air pump.	Diameter of screw propeller.	Pitch of screw propeller.	Distance between centres of propellers.
ft. in.	ft. in.	ft. in.	tons.	ft. in.		inches.	inches.		inches.	ft. in.	ft. in.	ft. in.
22 6	150 0	13 0	395	9 0	120	26	21	Injection.	8½	7 0	14 6	8 9
23 0	165 0	13 6	425	"	"	"	"	"	"	7 5	"	"
"	"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"	"
34 0	225 0	22 0	1,258	17 0	150	H. 24 L. 50	24	"	12	8 10	16 0	11 8
25 0	175 0	15 0	531	9 6	200	34	21	"	11	8 3	16 0	10 5
23 0	165 6	13 0	425	9 0	120	26	21	"	8½	7 0	14 6	8 9
"	"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"	"	"	"	"
11 10	57 6	7 0	35	4 10	30	12	11	High pressure.	None.	3 8	7 4	4 6
23 6	200 0	13 4	546	9 6	200	34	21	Injection.	11	8 0	16 0	9 5
15 0	85 0	6 6	91	2 9	30	12	11	High pressure.	None.	3 6	7 4	4 6
"	"	"	"	"	"	"	"	"	"	"	"	"
34 0	265 0	28 0	1,500	16 0	350	H. 31 L. 62	24	Surface.	11	10 6	18 0	12 0
17 0	100 0	6 6	138	3 6	30	12	11	Injection.	5¾	4 0	7 6	5 4
32 0	160 0	13 3	737	10 0	200	34	21	"	11	8 0	16 0	9 5
24 6	200 0	13 4	592	9 6	"	"	"	"	"	"	"	"
28 0	250 0	15 6	972	10 0	300	40	22½	"	13	9 2	17 3	10 9
"	"	"	"	"	"	"	"	"	"	"	"	"
27 0	230 0	14 6	829	9 6	250	37	21	"	12	8 9	16 0	10 0
21 6	190 0	13 0	436	10 0	120	26	21	"	8½	7 0	14 6	8 9

Tabular Statement *of Marine Engines constructed by Messrs. John Penn & Son, Greenwich, supplied by the firm.*

Screw Engines.

	Minotaur.	Achilles.	Warrior.	Black Prince.	Resistance.
Diameter of cylinder,	104¼	104¼	104¼	104¼	70¾
Length of stroke,	4 ft. 4 in.	4 ft. 0 in.	4 ft. 0 in.	4 ft. 0 in.	3 ft. 6 in.
Revolutions per minute,	—	52½	54¼	51¾	68 to 69
Diameter of screw,	24 ft. 0 in.	24 ft. 0 in.	24 ft. 6 in.	24 ft. 6 in.	18 ft.
Pitch of ditto,	25 ft. 6 in.	25 ft. 6 in.	30 ft. 0 in.	30 ft. 0 in.	21 ft.
Nominal h p.,	1350	1250	1250	1250	600
Indicated h p.,	—	5746	5471	5146	2424
Speed of ship,	—	14·25 knots	14·35 knots.	13·31 knots.	11·84 knots.
Date of trial,	—	Dec. 28, 1864.	Oct. 17, 1861.	Aug. 30, 1862.	Sept. 23, 1862.

Paddle-Wheel Engines.

	Esploratore.	Taliah.	Izzeddin.	Victoria.	Prince Imperial.
Diameter of cylinder,	72 in.	72 in.	66 in.	58 in.	52½ in.
Length of stroke,	5 ft. 0 in.	5 ft. 0 in.	5 ft. 0 in.	4 ft. 6 in.	4 ft. 0 in.
Revolutions per minute,	40	39	41½	42	48 to 49
Diameter of axis of wheel,	19 ft. 0 in.	19 ft. 0 in.	17 ft. 6 in.	17 ft. 6 in.	14 ft. 11 in.
Length of floats,	10 ft. 0 in.	10 ft. 0 in.	10 ft. 0 in.	7 ft. 10 in.	8 ft. 0 in.
Depth of ditto,	4 ft. 0 in.	4 ft. 6 in.	3 ft. 10 in.	3 ft. 6 in.	3 ft. 2 in.
Nominal h. p.,	350	350	300	220	180
Indicated h. p.,	2556	2540	2373	1640	1480
Speed of ship,	17·27 knots.	17·74 knots.	16·5 knots.	16·83 knots.	16·3 knots.
Date of trial,	May 6, 1863.	Dec. 28, 1863.	Sept. 19, 1864.	Sept. 3, 1861.	Sept. 28, 1864.

The following is a list of engines constructed by Messrs. Maudslay, Sons & Field for H. M.'s Navy since 1851 to the present date, kindly furnished by Joshua Field, Esq.:

	Horse-power, nominal.
Engines, &c., for 75 Screw Vessels, ...	Total, 37,570
" 26 Paddle "	" 6,340
" 69 Screw Gunboats, ...	" 4,260
Total,	48,170

THE FOLLOWING TABLE *gives particulars of some of the principal Marine Engines recently constructed by Messrs. R. Napier & Sons, Glasgow.*

NAMES OF VESSELS.	Paddle or Screw.	Material.	Tonnage. O. B. M.	Kind of Engine.	Number of cylinders.	Diameter of cylinder.	Length of stroke.	Nominal horse power.	Kind of Boilers.	Kind of Propeller.
						inches	ft. in.			
Coromandel, ...	Screw	Iron	—	Plunger, direct	2	50	2 6	250	Tubular	Common
Gunboat for H. E I. Company,	"	—	—	Horizontal, high pressure	2	18	1 6	80	"	"
Emperor Alexander, .	"	"	—	Plunger, direct	2	60	3 0	350	—	"
Islesman, . . .	"	"	$197\frac{81}{94}$	Horizontal	2	$24\frac{1}{8}$	3 0	80	Tubular	"
Victoria, . . .	Paddle	"	$144\frac{76}{94}$	Oscillating	2	$27\frac{1}{16}$	3 0	44	"	Radial
Fifeshire, . . .	"	"	—	Inclined	2	$36\frac{1}{8}$	3 6	82	Lamb's flue	Eccentric
Chevy Chase, . .	"	"	$963\frac{3}{94}$	"	2	$72\frac{1}{8}$	8 0	416	Tubular	"
Royal William, . .	Screw	Wood	—	Plunger, direct	2	$65\frac{1}{8}$	3 0	500	"	Griffith's
Cormorant, . . .	"	"	—	"	2	$45\frac{1}{8}$	2 0	200	"	"
Scotia, ...	Paddle	Iron	$4050\frac{28}{94}$	Side lever	2	100	12 0	1000	"	Radial
Orestes, . . .	Screw	Wood	—	Plunger, direct	2	$60\frac{1}{2}$	3 0	400	"	Griffith's
Clan Alpine, . .	Paddle	Iron	$1507\frac{30}{94}$	Inclined	2	64	8 0	400	"	Eccentric
Wolf, ...	"	"	870	"	2	61	6 0	275	"	"
Rolfe Krake, . .	Screw	"	$1091\frac{13}{94}$	Horizontal, direct	2	48	2 0	235	"	Griffith's
Osman Ghazy, . .	"	"	$4221\frac{51}{94}$	"	2	92	4 0	900	"	"
Abdul Aziz, . . .	"	"	$4221\frac{51}{94}$	"	2	92	4 0	900	"	"
Orkman, . . .	"	"	$4221\frac{51}{94}$	"	2	92	4 0	900	"	"

Total number constructed by this firm, from 1851, inclusive—Screw engines, 87; Paddle engines, 39.

The ratio of fuel consumed in pounds per hour, to the actual horse power per hour expended may be taken as follows: Engines of ordinary construction, power, 1·0; fuel, 5 to 6. For expansive working engines, with superheating and surface condensation, thus: Power, 1·0; fuel, 2·50.

I am deeply indebted to several eminent firms for their courtesy and the practical information received and personally given. Messrs. John Penn & Son, of Greenwich, have kindly given me a tabular statement of much value to the profession and Society. I am advised by this firm that a more extensive list of their trunk engines may be found in the *Artizan* journal for March, 1859, and November, 1861. The list now presented commences from the latter date; also, that with their class of engines their consumption of fuel is about 4 lbs. per actual horse power per hour for those of ordinary construction, and about 2·5 lbs. per actual horse power per hour for expansive engines, with superheated steam and surface condensation. This firm has displayed a warm interest in the present paper, by kindly lending the photographs and splendid working models, which I have the pleasure of laying before you.

Messrs. Maudslay, Sons & Field have kindly lent photographs of their late improvements in marine engines. From personal interviews, I am enabled to present the Society with valuable information, particularly as follows: The amount of fuel consumed, per horse power actual, for ordinary engines by this firm is 5 lbs., in some cases less, and in others more. For three cylinder expansive engines, with surface condensation and superheating, the consumption is reduced to 2·25 or 2·5 lbs. per horse power actual. These engines cut off at one-seventh of the stroke producing an almost correct indicator diagram. In one example shown me, the nominal horse power was 150; with a pressure of steam 25 per square inch, the indicator diagram produced a result of 875 actual horse power, being in the ratio of 1 to 5·833, which may be said to be an exceptional result for screw engines. This firm has constructed, since 1851 to the present time, the following number of engines and boilers: Of screw engines, 183; of paddle wheels, 30. The highest nominal power of one pair of engines yet constructed by this firm is 1350, and the lowest, 10.

The Messrs. Rennie have kindly lent me models and photographs of the different classes of engines they are in the habit of constructing. I am informed by this firm that the consumption of fuel for ordinary engines is: Actual horse power 1, fuel 5. In the case of surface heating, surface condensation, and expansion—Actual horse power, 1, fuel consumed, 2·5; showing a reduction of 50 per cent. on that of the ordinary kind, which is about equal to the other firms.

Valuable statistics have been supplied to me by Messrs. R. Napier & Son, of Glasgow, giving particulars of the ships, engines, &c., constructed by them from 1851, to the present time. From these I have made a selection for publication. This firm has also kindly presented me with splendid photographs of their engines, &c., which are hung for inspection.

With reference to twin screw propulsion, I am deeply indebted to the firm of Messrs. Dudgeon, of Blackwall. They have kindly furnished for this occasion practical statistics of the proportions of vessels and engines constructed by them since the year 1851 to the present time.

In conclusion I must apologize for the length of my present paper; but I beg to observe, that had I extended my remarks to twice or thrice the present length, I should even then have failed of doing justice to this subject which is undoubtedly one of national importance. To the credit of those concerned it can be truthfully said, that, in comparison with other nations, the productions of our marine engineers maintain that high standard for excellency of design and workmanship which has ever characterised the natives of Old England.

(To be continued.)

Suggestions on Drainage Works and Water Supply.

By Robert Rawlinson, C.E.

From the London Civil Engineer and Architect's Journal, August, 1865.

A valuable collection of instructions and suggestions relative to sewers, drains, and water-works has recently been issued by Mr. Robert Rawlinson, one of the Government engineers. Local surveyors, contractors, and others engaged on works of this nature intended to undergo Government inspection, will find them very useful for reference. The rules and suggestions are as follows:

Before a scheme of sewerage is devised, the district should be fully examined, so as to obtain a correct idea of the drainage area, or the several drainage areas; inquiry should then be made to ascertain how surface water has passed off up to the time of such examination, and with what effects. Main sewers and drains should be adapted to the town area, length of streets, number of houses, surface area of house yards and roofs, number of street gulleys, and volume of water supply.

Sewers and drains, in wet subsoil, should be made to act as land drains.

The following rules are general; each surveyor must, however, use his own judgment, and make the best arrangements possible under the circumstances with each special area, and with the materials at command:

1. Natural streams should not be arched over to form main sewers.
2. Valley lines and natural streams may be improved, so as to remove more readily surface water and extreme falls of rain.
3. Main sewers need not be of capacity to contain flood water of the area drained; such flood water may be passed over the surface in most cases without causing injury.
4. Main sewers should be laid out in straight lines and true gradients, from point to point, with manholes, flushing, and ventilating arrangements at each principal change of line and gradient. All manholes should be brought up to the surface of the road or street to allow of inspection, and should be finished with a cover easily removable.

5. Duplicate systems of sewers are not required. Drains to natural streams in valley lines for storm waters may be retained, and may be improved or, if necessary, enlarged.

6. Earthenware pipes make good sewers and drains up to their capacity. Pipes must be truly laid and securely jointed. In ordinary ground they may be jointed with clay. In sandy ground special means must be used to prevent sand washing in at the joints.

7. Brick sewers ought to be formed with bricks moulded to the radii.

8. Brick sewers should in all cases be set in hydraulic mortar or in cement. In no case should any sewer be formed with bricks set dry to be subsequently grouted.

9. Main sewers may have flood water overflows wherever practicable, to prevent such sewers being choked during thunderstorms or heavy rains.

10. Sewers should not join at right angles. Tributary sewers should deliver sewage in the direction of the main flow.

11. Sewers and drains at junctions and curves should have extra fall to compensate for friction.

12. Sewers of unequal sectional diameters should not join with level inverts, but the lesser or tributary sewer should have a fall into the main at least equal to the difference in the sectional diameter.

13. Earthenware pipes of equal diameters should not be laid as branches or tributaries—that is, 9 ins. leading into 9 ins., or 6 ins. into 6 ins., but a lesser pipe should be joined on to the greater, as 6 ins. to 9 ins., 9 ins. to 12 ins., 12 ins. to 15 ins.

14. House drains should not pass direct from sewers to the inside of houses, but all drains should end at an outside wall. House drains, sink pipes, and soil pipes should have means of external ventilation. The largest block of buildings may have every sewer outside of the main walls. No foul water drains nor cesspit should be formed beneath any house basement. All fluid refuse should pass at once from the drains to the sewers and from the sewers to the outlet.

15. Sinks and water-closets should be against external walls, so that the refuse water or soil may be discharged into a drain outside the main wall. Down spouts may be used for ventilation, care being taken that the head of such spout is not near a window. Water-closets, if fixed within houses, and having no means of direct daylight and external air ventilation, are liable to become nuisances and may be injurious to health.

16. Inlets to all pipe drains should be properly protected.

17. Side junctions should be provided in all sewers and drains. The position should be sketched, and indicated by figures in a book or on a plan. Side junctions not used at once, should be carefully closed for subsequent use.

18. A record should be kept by the surveyor of the character of the subsoil opened out in each street sewered or drained.

19. Sewers and drains should be set out true in line and in gradient. All the materials used should be sound, and the workmanship should be carefully attended to.

20. Sight rails should be put up in each street before the ground is opened out, showing the centre of each water sewer and depth to the invert.

21. Sewers having steep gradients should have full means for ventilation at the highest points.

22. Tall chimneys may be used with advantage for sewer and drain ventilation, if the owners will allow a connexion to be made.

23. Sewers outlet works should be simple in form, cheap in construction, and so arranged as to remove all solids, sediment, and flocculent matter from the sewage.

In executing town sewers and drains, danger may be anticipated from several conditions, as under:

Where a street or place is narrow, with buildings on both sides, and where the trench is deep; where the substrata is clay or marl, made ground, loose earth, bog and silt, quicksand, or any combination of such strata.

Quicksand is the most difficult to deal with, and, as a rule, such ground should only be opened in short lengths; this ground may require to be close timbered, and in such cases stable litter and ashes will be found useful to pack behind and betwixt the polling boards.

Sound looking clay or marl may require careful timbering to prevent heavy breakings from the sides of the trench. When such ground "sets" heavily, the sewer, if of bricks, may be seriously injured; if of earthenware pipes, it may be ruined by cracking, or by crushing and distorting the line of sewer or drain pipes.

As a rule, all sewer and drain trenches in towns should be carefully timbered, and such timbering must either be left in, or be most carefully removed as the trench is filled.

The houses and buildings in narrow streets may require to be propped and stayed; if so, such props and stays ought not to be removed until the sewer or drain has been completed, and the ground become perfectly consolidated.

In many cases it will be cheaper, because safer, to leave timbering in deep trenches, and where there is special danger the trench may be filled with concrete.

A foreman in charge of sewer works is expected to be on the watch to see that the men execute the work safely. The local surveyor must see that timber sufficient in quality and quantity is supplied to secure all open trenches, and the buildings on either side.

Where ground is known to be specially dangerous, all available precautions must be taken to prevent accidents.

It is of the utmost importance to impress upon local surveyors the necessity of care in setting out main sewerage works and house drains with accuracy, in choosing sound materials, and in properly superintending the works during their progress. House drains should be so arranged as to be capable of removing all water, soil, and fluid refuse from yards, roofs, and interiors of houses to the sewers, without any risk of gaseous contamination to such houses.

Street sewers should be capable of conveying all sewage to some

common outlet, without retaining sediment in them. All sewers and drains should have arrangements for full ventilation at such points and in such manner as not to cause any nuisance. Charcoal (as proposed by Dr. John Stenhouse) may be used to filter and disinfect sewage gases at all manholes and other ventilators.

If the fluid sewage can be applied to land for agricultural uses, means should be provided for effecting this purpose.

Water-closets should have a daylight window (not a "borrowed light") and fixed means for ventilation, which can neither be seen nor be tampered with. Permanent openings, equal to a slit of 12 inches in length and 1 inch wide, should be provided. The cover or lid of the seat should be made to close and leave the valve handle free, so that the contents of the closet may be discharged with the lid closed down. At all times when a water-closet is not in use the lid or cover should be closed.

Water Supply.

Where a district is to be supplied with water, all other things being equal, the softest and purest water should be adopted.

A water supply may be gravitating, or the water may be pumped by steam power. The relative economy of one or the other form of works will depend on details of cost and quality of water. As a rule, gravitating works require the largest capital. The annual working expenses of a pumping scheme will frequently be greatest.

1. Plans and sections of the proposed gathering ground of any storage reservoir, geologically colored, should be produced on a scale not less than six inches to the mile.

2. The area of the gathering grounds proposed to be affected should be given in statute acres.

3. Plan of storage reservoir and works immediately connected therefrom must be at a scale not less than four chains to the inch.

4. The fall of rain in the district for not less than seven years, ought to be produced.

5. Trial shafts shall be sunk in the centre line of the site of the proposed embankment, at a distance not greater than 100 feet apart. The results and details relative to the stratification obtained from such trial shafts shall be produced.

6. Plans of the proposed outlet and other works, in detail, at a scale of not less than 20 feet to 1 inch must be prepared. Such details should exhibit the embankment in plan, and also cross sections at the deepest part of the proposed embankment. The following detail drawings shall also show:

a. Top bank width of embankment.
b. Inner and outer slope of bank.
c. Puddle wall and puddle trench.
d. Relative level of by-wash below top bank level.
e. Outlet works.
f. By-wash and by-wash conduit.

7. The capacity of the reservoir, to the level of the by-wash, to be stated in cube feet.

8. No puddle wall shall be less in width at the top water line, in any part of the embankment, than 8 feet, and shall increase for each foot of vertical height not less than 1 inch in width on each side of such puddle wall, down to the ground line at the deepest part of the embankment. Similar proportions shall be preserved throughout the entire line of the puddle wall. The puddle trench shall be filled entirely with puddle.

9. The inner slope to the embankment shall not be less than three horizontal to one vertical. The outer slope shall not be less than two and a half horizontal to one vertical. Embankments should be formed in layers of earth not more than 12 inches deep, spread evenly over the entire area of such embankment; neither railways nor tramways should be used on a water-works embankment, but dobbin carts or wheelbarrows. An embankment should be formed evenly and regularly, the puddle wall and the rest of the bank being brought up simultaneously.

10. The finished top bank width of any reservoir shall not be less than the following dimensions, namely:

An embankment	25	feet deep,	not less than	6	feet wide.
"	50	"	"	12	"
"	75	"	"	18	"

Intermediate, or lesser, or greater depths of embankment may have proportionately arranged widths.

11. The finished top bank level of any reservoir shall not be at less than the following elevations above the edge of the by-wash or top water line of a full reservoir, namely:

An embankment	25	feet deep,	not less than	4	feet.
"	50	"	"	5	"
"	75	"	"	6	"

Intermediate, or lesser, or greater depths of embankment may have proportionately arranged relative top bank and by-wash levels.

12. Each impounding reservoir shall have full and free by-wash space not less than three feet in length for every hundred acres of gathering ground; such by-wash, where practicable, to be formed in the solid ground.

13. Cast iron pipes, culverts of timber, or other material liable to decay, shall not be used for outlet discharge, or for overflow works, if required to be buried under or within any reservoir embankment in such manner, and in such dimensions, as to preclude repairs, and endanger the structure by decay. Valves and sluices should be placed within the line of puddle wall.

14. A reservoir embankment shall, at all times, be preserved at its full height, and the relative level of the top bank and by-wash be preserved.

15. All reservoir works and apparatus, such as goits, culverts, tunnels, conduits, by-washes, cloughs, sluices, valves and working machinery connected with such cloughs, sluices, and valves, shall be maintained sound and in good working order.

Reservoirs for service distribution should be covered.

Water should not be exposed in open reservoirs and tanks after filtration.

Cast iron pipes, properly varnished, should be used for street mains. It is not advisable to use mains less in internal diameter than three inches.

Lead should not be used either in service pipes or house cisterns. Wrought iron tubes with screw joints may be used for house service. All house taps should have screw joints, and be of the description known as screw down, so as to admit of easy repairs.

In jointing and fixing wrought iron service pipes care should be taken to insert double screw joints at convenient points, to allow the removal of a length of pipe for alterations and repairs.

Up-bends should be avoided, or a tap should be inserted to allow any accumulation of air to escape.

Wrought iron service pipes are cheaper, stronger, and more easily fitted than service pipes of lead. Certain sorts of made ground in towns act rapidly and injuriously on both lead and iron pipes—furnace ashes, waste gas, and chemical refuse, old building refuse containing lime and other such material. Pipes should not be laid in such material without a lining of sand or puddle, or other special protection.

Earthenware pipes may be used for water conduits, provided the joints are not placed under pressure.

A public supply of water should not be less in volume than 20 gallons daily per head of the population. This, in towns below 20,000 population, will include water for public purposes and for trade requirements. High pressure and constant service should be secured wherever practicable.

Water at and below six degrees of hardness is "soft" water, above this range water is "hard."

Hardness in water implies one grain of bicarbonate or sulphate of lime in each gallon of water.

Each degree of hardness destroys 2½ ounces of soap in each 100 gallons of water used for washing. Soft water is, therefore, commercially, of more value than hard water, in proportion to the worth of 5 ozs. of soap to each 100 gallons for each degree of hardness. But soft water is also more wholesome, and effects saving in other operations—tea making, and in generating steam power.

The Field Boiler, its Principle, Construction, and Action.

By Francis Wise, C.E., M. Inst. E.S., &c.

From the London Civil Engineer and Architect's Journal, June, 1865.

(With an Engraving.)

The object of what is commonly known as a steam boiler, is to impart the heat evolved by the combustion of any suitable fuel, to water contained in a close vessel, in such a manner as that evaporation may ensue, and that the vapor given off may be employed as a source of power or for other purposes; and further, it must be admitted that,

other things being equal, the less time and space occupied in evaporating any given quantity of water the better. It is evident, however, that if increased rapidity of evaporation is to be achieved at the cost of economy of fuel, of space, or of safety, the advantages of quick evaporation will be either neutralized or diminished.

In the Cornish and other boilers in that class, the heat generated in the furnace is not absorbed with sufficient rapidity by the water to render quick combustion economical, inasmuch as with it a considerable proportion of the heat evolved by the burning fuel, instead of being taken up by the water, is either absorbed by the brickwork of the flues or passes away uselessly by the chimney. The reason, therefore, of the superior economy of slow combustion in Cornish boilers is, that they require a considerable time to take a fair per centage of the heat generated, and that unless sufficient time is allowed them for doing so, a certain proportion of the heat is wasted, which indeed simply amounts to saying that the Cornish boiler is imperfect in principle, (insomuch as, beyond a comparatively low limit, it is incapable of utilizing a proper proportion of the heat capable of being generated in its furnace,) and does not in any way go to show that, with a boiler capable of rapid absorption, slow combustion is either advantageous or desirable. At all events, it is obvious that, if by using an improved construction of boiler we can evaporate the same amount of water as is evaporated by the best Cornish boilers, with greater safety, and at least equal economy of fuel, in a space of about one-sixth what is necessary under the Cornish system, there is a clear gain of much importance; and if to this can be added greatly increased accessibility and non-liability to wear and tear in the body of the boiler, we shall have made a decided and highly important step in advance.

How, then, is this to be done? It is clear that anything approaching to the Cornish system, with its long and partly useless flues and large body of sluggishly circulating water, is out of the question. Turning, then, to multitubular boilers, in which the heated products of combustion are conveyed from the furnace to the chimney, by a number of small tubes passing through the water space and intended to impart heat to the water, and what do we find to be the result? Why, that flame entering the tubes is almost immediately extinguished, through want of a proper supply of oxygen, and that the heated products of combustion, to a great extent, pass through the tubes without their heat having been absorbed by the water surrounding them, and that the more rapid the combustion, the greater (owing to the imperfect circulation) is the proportionate loss of heat. This, then, in its present form, is evidently not the system whereby the end desired is to be achieved.

If these premises be correct, two things are clear, viz: first, that we cannot use the Cornish system with its large body of inert water; and secondly, that the plan of passing the heated products of combustion in threadlike streams through the water space, as in the ordinary multitubular boiler, is also practically incorrect.

Let us now suppose that, instead of passing the products of combus-

tion in small streams through the water, we cause the water itself to pass in like streams (and with a rapidity of flow self-proportioned to the heat whereby it is surrounded) into and through the hottest part of the furnace. The result will then be that, with slow combustion, the circulation will be slow, so that the quantity of water presented to the action of the fire in any given time will be exactly suited to its heat imparting power; and that if the rapidity and intensity of the combustion be increased, the rapidity with which the water will pass through the furnace will be proportionately increased, and this will be so even although the fire be urged to give out the greatest possible amount of heat. Hence it is evident, as the velocity of the circulation is in all cases regulated by the heat giving power for the time being of the furnace, it matters not whether the combustion be slow or quick, excepting that, in the latter case, we shall be enabled, by the greater velocity with which the streams of water pass through the furnace, to evaporate a proportionately greater quantity through the same space. Now, this is precisely the principle of the boiler under notice, the practical results of which entirely corroborate the foregoing remarks, and satisfactorily prove that the principle of submitting the water, in small and rapidly circulating streams, to the most intense heat of the furnace, is the true one, and superior to any other yet introduced; as also that, in this way, almost the whole of the heat generated in the furnace (with the exception of what is necessarily employed for the purpose of maintaining a sufficient draught) may be utilized in the production of steam, and that economy of space and weight may thus be made to go hand-in-hand with that of fuel.

A consideration of the construction of the Field boiler will at once show how these effects are produced, while the boiler itself is at the same time rendered safer than any other kind of boiler in existence. It should, however, be first mentioned, that the principle of construction adopted in the Field boiler is not only applicable to boilers for stationary purposes, but also with equal advantage to those of the marine and portable class; and, with reference to the latter class, has proved itself capable of going through the most severe work uninjured, under which other boilers have required constant repair, and have never, at the best, been free from leakage. The construction of the Field boiler is this:

It consists of two principal parts, namely, the water and steam space, or body of the boiler, and the furnace or chamber wherein the fuel is burnt. For stationary purposes the boiler is made cylindrical in form with an annular space *a*, surrounding the furnace *b*, as shown in Fig. 1, of the accompanying Plate I, but the form may be readily varied and adapted as required to suit any peculiarities of circumstance or position, whether for land or marine purposes. In the case of the cylindrical vertical boiler referred to, a number of tubes *c*, placed annularly around a fire-tube *d*, passing upward through the boiler, hang down or are pendant from the under side of the water and steam space *e*, into the furnace *b*.

These tubes are open at their upper ends into the water space, and,

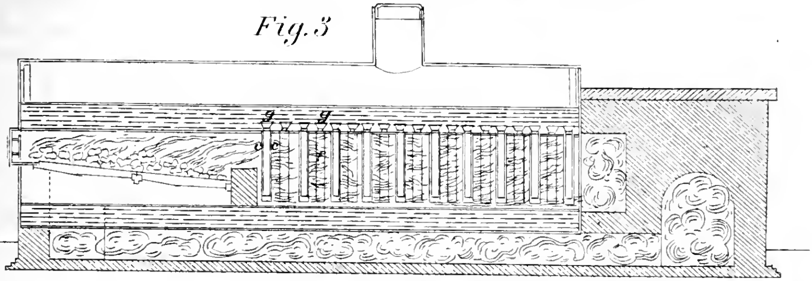
being closed at the lower ends, are consequently (when the boiler is in readiness for starting) entirely filled with water, the top level of which is some inches above their upper ends. Within each of these tubes is freely suspended, by means of feathers x, a smaller tube f, open at both ends, the upper end of which rises above the level of the upper end of the outer tube c, but is short of reaching the bottom of it. The tops of these inner tubes are provided with trumpet or funnel-shaped mouths or deflectors g, which, as will be seen, perform an important part in the action of the boiler. A baffle plate or cylinder h, suspended beneath the opening into the flue-tube d, which passes upwards through the boiler, prevents any portion of the heat of the furnace from passing away without having first enveloped and become almost entirely absorbed by the pendant tubes and the water circulating within them.

Boilers upon this principle are peculiarly adapted for marine purposes, insomuch as not only is the body of water which they contain, and which is liable to surge from side to side by the roll of a vessel, considerably less than in boilers of the ordinary construction, but it has been found that they may be worked with water completely saturated with salt. Indeed, experiments which have been made show that even with a supersaturated solution; that is to say, a solution which after saturation has been further evaporated until a considerable portion of salt is held only in mechanical suspension, the tubes work well, and will, on the relighting of the fire, absolutely eject the salt which has settled in them during a period of rest, even although its depth may be sufficient to cover the bottoms of the inner tubes. A boiler of this kind is shown in Fig. 2, in which b is the furnace, the flame and heated gases from which, after passing the bridge q, continue onward among a series of pendant double tubes, and returning along a flue—also containing pendant double tubes—towards the front of the boiler, pass away by the uptake d. The double tubes thus arranged, and not too closely packed, permit the flame of the furnace to play among them for a considerable distance without extinction; and by the position of the surface they present to the flame and heated gases are most effective in their more economical results. This was curiously shown in the case of a Cornish boiler, to which a few of the double tubes were applied in the main flue, immediately behind the bridge, in the manner shown at Fig. 3. In this case the amount of heating surface added to the boiler was 10 per cent., but the saving of fuel, instead of being in the same proportion, was more than 20 per cent.; and it was found in this case, when there was only a thickness of about $\frac{3}{8}$-inch of iron in which to fix the tubes—as had previously been found with boilers having tube plates of greater thickness specially intended to receive and support the double tubes—that such was their perfect freedom of expansion and contraction, that there was not a drop of leakage.

It will thus be seen that this system, in addition to its other advantages, does away with that serious and inevitable defect of tubes fixed at both ends, namely, leakage, the destructive effects of which are well known to every person who has paid any attention to the working of boilers; and further, the same feature which does away with

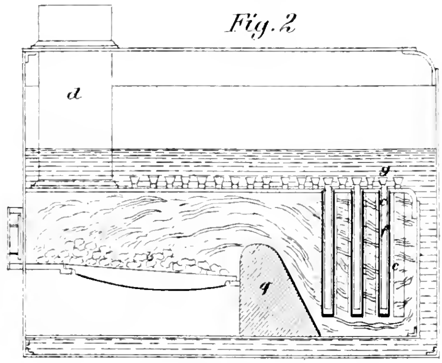
THE "FIELD" STEAM BOILER.

Fig. 3



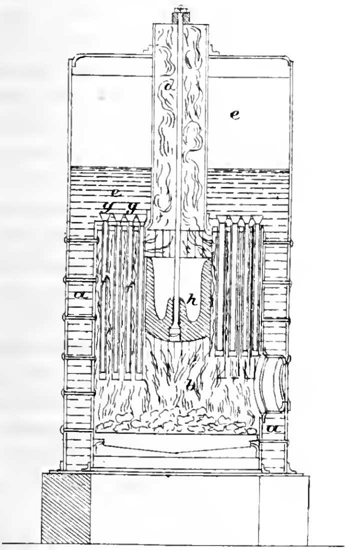
Cornish Boiler with Field's Tubes

Fig. 2



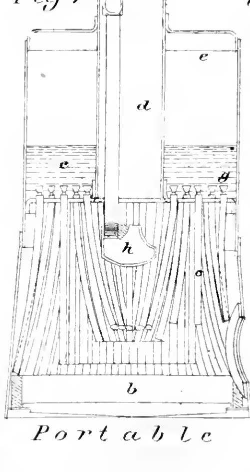
Marine

Fig. 1



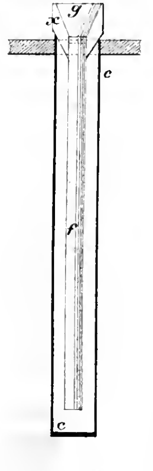
Stationary

Fig 4



Portable

Enlarged View of the Tubes c & f



[illegible]

the very serious evil referred to, has an important effect in lessening the first cost of the boiler, insomuch as it enables the tubes to be securely and perfectly fixed, simply by a very slight expansion of their upper ends, without the use of any ferules or other objectionable arrangement. To fix the tubes all that is necessary is to make the holes in the tube-plate slightly conical, their diameters at the lower surface of the plate being equal to those of the tubes, and their upper diameters somewhat larger, and then, after having slightly expanded the upper end of the tube, to place it in its intended position, and by means of one or two blows with a hammer upon a steel conical mandrel inserted in its upper end, to further expand the tube, so that it may fill and jam itself in the hole in the plate.

The facility with which a tube may thus be fixed is a matter of great importance in case of injury occurring to a tube during the working of the boiler, as at the worst it involves only a trifling delay before the damaged tube can be replaced and the boiler again put in perfect working order, without its being necessary even to call in the assistance of a skilled workman, a class of individuals generally found to be unobtainable at the very time when most urgently wanted.

The boilers for stationary purposes as already described, though calculated for steady and continuous working, and economical in consumption of fuel, are not, at the same time, so heavy or cumbrous as to preclude their being used with advantage for various description of portable engines, as, in point of fact, they are lighter than those ordinarily used for such purposes, and, where extreme lightness is not of paramount importance, are certainly the most desirable form of boiler to employ. There are cases, however, and that of steam fire engines is one of them, in which extreme lightness and portability in the boiler, combined, with a power of raising steam with great rapidity, are of more importance than economy in fuel. In such cases it is obvious that the weight of the water casing, and of the water contained in it, would constitute a comparatively serious objection to the employment of the water cased boiler, which would be also further objectionable on account of the extra time required to heat the additional quantity of water contained in the casing. For purposes, therefore, of the kind referred to, the boiler used is of the type represented at Fig. 4, in which the water casing is entirely dispensed with, and the tubes used —which are of smaller diameter than those used in the other types—are so arranged as that the lower ends of the outer circles constitute an almost continuous casing around the fire-grate.

In working these boilers, a steam jet is used as soon as steam appears, for the purpose of urging the draught, and is continued in action until the engine is started, when the jet is shut off and the draught is maintained by the exhaust steam which passes by the pipe into and through the hollow baffle, whence it issues into the chimney. These boilers were designed for and are used with the greatest success in the steam fire engines manufactured by Messrs. Merryweather & Sons, whose small class engines, weighing in all about 30 cwt., raise steam from water, which, at starting, may be little above freezing, to a pres-

sure of 100 lbs. on the square inch in $9\frac{1}{4}$ minutes, and maintain the pressure undiminished while doing absolute work, in raising water to the extent of over twenty horses power. The engine Sutherland, which weighs complete only 2 tons 18 cwt., is fitted with a boiler of the same class, and has shown wonderful rapidity in raising and generating steam. Thus, at the Crystal Palace, this engine raised steam from cold water to a pressure of 100 lbs. on the square inch in ten minutes, and subsequently threw a jet from a $1\frac{5}{8}$-inch nozzle vertically to a height of 200 feet, and maintained it steadily up to a height of more than 180 feet, for over five and twenty minutes, showing itself capable of continuing to do the same for any length of time desired. The boilers of the first named class of engine are 2 feet 3 inches in diameter, and, inclusive of furnace, are only 4 feet 6 inches high, while that of the latter is 3 feet 6 inches in diameter, and 4 feet 6 inches high.

In order to obtain the required large amount of steam from boilers of such disproportionately small dimensions as these, it is obviously necessary that the heat of the furnace be of the most intense character, and it is equally obvious that, in order to maintain it to that intensity, a very large supply of air must be drawn through the burning fuel, and as this can only be done by means of a proportionately fierce draught, it naturally follows that a considerable per centage of heat is wasted, not, indeed, by reason of any deficiency of absorbing power in the boiler, but on account of the disproportionate strength of draught required to draw the necessary amount of air through the furnace, and which, consequently, not only compels the rapid rush of too large a proportion of the heated gases up the chimney, but also, at the same time, carries with them a by no means insignificant amount of the burning fuel itself. Yet, notwithstanding the disadvantages under which they thus necessarily labor, and which are in their nature so inimical to economy in fuel, the workings of these boilers show results quite equal to those of the majority of ordinary stationary boilers, and therefore form another convincing proof, if any were required, of the correctness of the principle upon which their construction is based.

A consideration of what takes place in the working of the Field boiler will at once clearly show why it should in all cases contrast favorably with other boilers employed under similar circumstances. Thus, taking for example the size of stationary boiler known as 80-horse, but which will in reality work with ease up to 120 horse power, the outer diameter of this boiler is 6 feet 6 inches, and its height 8 feet 8 inches. It contains 490 square feet of tube surface, the outer tubes being 2 inches in internal and $2\frac{1}{4}$ inches in external diameter, and the inner 1 inch in diameter. Now, upon lighting the fire, the water in these tubes immediately commences to circulate every increment of heat, however trifling, added to the water contained in the annular spaces between the inner and outer tubes, lessening its specific gravity and causing it to ascend, and cold water to consequently descend the inner tubes to supply its place. This action goes on increasing gradually in rapidity until ebullition commences, at which time the velocity of flow is increased enormously, owing to the great difference between the specific gravity of

mixed water and steam ascending in the annular spaces, and that of the solid water descending the inner tubes.

Taking the velocity of flow down the inner tubes at 10 feet per second, and the number of tubes at 289, we shall have a quantity of water equal to about 96 gallons passing down into the furnace, and being submitted to its most intense action in every second of time. Moreover, owing to the principle of action of the tubes, the water so submitted necessarily belongs to the less heated portion of the contents of the boiler, and consequently possesses the greatest capacity for heat. Now, when we consider that an amount of water equal to the entire average contents of the boiler is thus passed into the furnace, with the intervention of only one-eighth of an inch of metal between itself and the fire, in every six seconds of time, some idea may be formed of the immense rapidity with which the heat of the furnace may be passed into the water, which may be further strengthened by reflection on the well known fact, that if it be attempted to harden a tolerably large piece of steel by plungiug it when hot vertically into cold water and hold it motionless in that position, the attempt will prove a failure, inasmuch as the water will fail to carry off the heat from the steel with sufficient rapidity to effect the hardening, but if, instead of holding the steel motionless as described, we move it more or less rapidly from side to side through the water, the hardening will be at once effected. Now, this is precisely the difference between the ordinary kinds of boiler and the one which forms the subject of this paper. In each case we have, on the one hand, a mass of water subjected to heat, and unable to change its position with sufficient rapidity to absorb the heat presented to it; and on the other, a constantly changing surface of fluid, carrying off the heat from the metal with great rapidity, and in case effecting the object desired.

Here, then, is one very obvious reason for the economical results achieved by these boilers, even under circumstances which might seem to put economy out of the question, the fact being simply that, in ordinary boilers, the circulation, left to shift for itself, has great difficulty in becoming of a decided character in any direction, so that the water, instead of taking off, or, as it may be expressed, rushing off with the heat from the metal as required, hangs about it, and with comparative slowness conducts it away. The consequence is that much of the heat passes into and away by the flues instead of into the water, and thus it is, as was before remarked, that slow combustion with ordinary boilers necessarily shows to better advantage than quick. It is important in discussing the merits of any boiler to advert to the difficulties, if any, likely to arise from the deposit on its surface of these troublesome matters, the sulphates and carbonates of lime, or other such compounds of them as are usually thrown down in the form of a hard scaly incrustation. It is well known that such deposits are encouraged by sluggish circulation, and that where the circulation is most feeble, as well as in the neighborhood of the feed pipe where the water first enters the boiler, the deposit is usually thicker than at any other places. Bearing this in view, we are naturally led to expect that the effect of very rapid

and constant circulation will be to prevent deposit in the channels wherein such circulation takes place, and are therefore scarcely surprised to find that the tubes of boilers of steam fire engines constructed upon the Field principle, and worked almost daily for two years, have remained entirely free from deposit.

It may be that some small part of this remarkable result is due to the continual changes of water, with which, from the nature of their duties, these boilers are worked; but assuredly, if that be so, the part borne by these changes in preventing incrustation is very small indeed. But allowing that continual change of water had some appreciable influence in the matter, stationary boilers on the Field system now at work show that with the most ordinary precautions there is practically no incrustation. The writer was present lately at the opening of one of these boilers for the usual quarterly examination, and is enabled to state that there was no hard or scaly deposit whatever. At the bottom of the water space there was a light colored mud, which, when dried, proved to be an impalpable powder, consisting, doubtless, of the matters which, in ordinary cases, are deposited in boilers in the form of hard incrustation, but which, in this case, had been kept in mechanical suspension until finally thrown down into the water space as described. The precautions which had been taken in this instance, and which were so thoroughly efficient, were of the most simple character, and consisted, first, in the employment of an inexpensive water heater, whereby some of the calcareous matters contained in the water were thrown down previous to its entrance into the boiler; and secondly, in the use in the water of a trifling quantity of composition, known as Buck's, and consisting, apparently, chiefly of soda, which seemingly had the effect of completing whatever was left undone by the heater.

These facts dispose of the only point suggested by practical men as likely to prove a source of difficulty with the Field boiler, and leave its important advantages of economy in fuel and of space, ease in firing, accessibility for examination and repair, and perfect safety, without any corresponding drawback.

Exploration of Palestine.

From the London Athenæum, July, 1865.

Last week we announced the return of Captain Wilson and his party from Palestine, with a large collection of drawings and observations.

On Thursday, he met the newly named Committee of the Palestine Exploration Fund, in the Jerusalem Chamber, Westminster, when he reported on the prospects of excavation in Syria, and particularly in Palestine. After much consideration of the means now placed at the disposal of the Committee—a sum of about 2000*l.*—and the great work to be accomplished, it was resolved, with the permission of the War Office, and the sanction of Earl Russell, to send Captain Wilson and his exploring party back to Jerusalem, instructed to make a general survey of the country with a view to the future operations of the Society

when it shall have obtained a larger measure of public support. He is to consider Jerusulem and Nabalus as his principal fields; he is to take levels and observations, to dig in the foundations of walls, to trace conduits and sewers, to examine tells and mounds, and otherwise carry on the preliminary business of exploration. The labors of the Committee are, therefore, commencing well, and if the members will keep clear of all controverted theories and individual crotchets, there is every hope of success. The danger lies there. The Committee is the result of many compromises—at present, it represents nearly all the schools of archæology; and its officers must take care to avoid the appearance of partizanship. Let all opinions have a hearing, and the public will have confidence in the wisdom of such measures as may be finally adopted. Captain Wilson will return to Palestine in October.

The Leveling of the Mediterranean.

From the London Athenæum, July, 1865.

The leveling from the Mediterranean to the Dead Sea has been performed with the greatest possible accuracy, and by two independent observers, using different instruments, and the result may be relied upon as being absolutely true to within three or four inches. The depression of the Dead Sea on the 12th of March, 1865, was found to be 1292 feet, but from the line of driftwood observed along the border of the Dead Sea, it was found that the level of the water at some period of the year, probably during the winter freshets, stands 2 feet 6 inches higher, which would make the least depression 1289·5 feet. Captain Wilson also learned from inquiry among the Bedouins, and from European residents in Palestine, that during the early summer the level of the Dead Sea is lower by at least 6 feet; this would make the greatest depression to be as near as possible 1298 feet. Most of the previous observations for determining the relative level of the two seas gave most discordant results. The Dead Sea was found by one to be 710 feet above the level of the Mediterranean, by another to be on the same level, by another to be 710 feet lower, and by another to be 1446 feet lower; but the most recent before that now given, by the Duc de Luynes and Lieutenant Vignes, of the French Navy, agrees with our result in a very remarkable manner, considering that the result was obtained by barometric observation, the depression given by them being 1286 on the 7th of June, 1864, which at most differs only 12 feet from the truth, if we suppose that the Dead Sea was then at its lowest. In my instructions to Captain Wilson, I gave directions for bench marks to be cut upon the rocks and buildings along the line leveled from sea to sea, and for a traverse survey to be made of the whole distance, upon which the places where the bench marks can be found can be represented. This traverse will be given with the plans in the atlas, as well as the diagram of the triangulation around Jerusalem, and these cannot fail to be of great value for any more extended surveys which may be hereafter undertaken in Palestine.

MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

Expansion and Propulsion.

All persons are familiar with the transcendent achievements of steam power, and almost all consider them prelusive to others still greater, but while every one sees what it does, comparatively few perceive how it is done. Ideas of it that reach no further than external features and movements of an engine are indefinite and more or less cloudy and chaotic. Even with engineers themselves, there are points on the evolution, treatment, action, and applications of the fluid far from being lucid and sharply defined. Opinions greatly vary. Two examples may here be quoted,—one of marked interest to the engineering community, the other of greater importance to the national and commercial marine: 1. The economy of expansion by cut-offs. 2. The virtue of *form* in propelling blades. The competing engines of the *Algonquin* and *Winooski* will go far to settle the first, but not the second, without removing the undershot water wheels, suspended as paddles, over the sides of both vessels.

Of the economy of stopping the flow of steam into a cylinder before the piston reaches its ends, there is and has been no diversity of opinions; the fact is palpable, and such has been the uniform practice since the beginning. The points in dispute are the extent to which the principle is urged, and the amounts of gain claimed. Prevailing opinions, right or wrong, have always governed, and much that is due only to reflection and demonstration is still yielded to popular dogmas, to interest and feeling. Inventors oftener build without data than with them, and, what is worse, their propositions are too commonly made bases of speculation. All this is natural, at any rate unavoidable; nor is it, on the whole, to be regretted that truth in mechanical, as in other departments of research, has to be reached through conflicts with interests and error. Without efforts to attain it we could neither be prepared to receive it, nor capable of appreciating it. That which costs little or nothing is held of small account.

While admirers of "independent" cut-offs dwell complacently on that part of the operation to which "the great saving" is attributed, others glance at what they hold as a full counterbalance. Thus, when a charge cut off at one-third drives the piston through the remaining two-thirds, a clean profit is claimed. To this other observers say nay; that against it should be placed the expenditure of two-thirds more power—steam—on the first part of the stroke than was necessary, and hence that what is gained at one point is lost in another; at all events, that the difference is rather slight than serious. But may not the surplus force on the first part be recovered and applied to the latter? No, not a particle. Misspent force can no more be recalled than misspent time. It vanishes with its action and no longer exists. Yet the steam is still in the cylinder: Granted, but it no longer possesses the power gone out of it. The power is in expansion, and while the piston was station-

ary it was intact, but diminished as that gave way before it. At a first glance the loss may not be apparent, but the difficulty will vanish when it is remembered that communication with the boiler is not closed till the piston has passed through the cylinder to the point fixed on for the cut-off to act. Till then, the loss is made good from the boiler, and consequently does not appear in the cylinder. Could unproductive or misapplied force, of any kind, be recovered and turned to profit, the economy of creation would be very different from what it is.

It would moreover be a marvel if additional power could be got out of a definite quantity of steam by increasing its tension—if one-third of a charge at 90 lbs. on the inch were more effective than a full one at 30 lbs. As well expect to spin more thread out of closely than loosely packed cotton. Compression can add nothing to the fibre or fluid. The gain, however, is ascribed to economy in expending the fluid rather than to an increase of its quantity, and engineers on both sides of the Atlantic have indorsed the system. The government experiments will, it is presumed, definitely settle the question. When they are completed and published we shall learn whether the principle of high or extreme expansion is to be preferred to the doctrine of those who hold that the available force of the charge can vary but little, whether compressed into $\frac{1}{10}$, $\frac{1}{4}$, or $\frac{1}{2}$ of its initial volume—that disbursing steam and money is much the same, a gold dollar going no further than a silver one, nor it varying in value, whether laid down in one piece, or in halves, quarters, or dimes. There are probably no expenditures of force unattended with loss or waste, but by no system of saving can the principle be reversed and the outlay of one portion command a return due to a greater.

It is to the second proposition this paper is intended more especially to invite attention—one of high import to the government, since it involves the question of speed, and that in vessels of war is vital, is everything. It has elsewhere been remarked that an increase of a few knots in our cruisers would have virtually ended the late horrible war two or three years ago, saved thousands of lives, and multiplied millions of money—that it may as well be obtained as current rates, and will be, though perhaps not without further struggling against a plain law of physics—plain and perfect to those who look into it, a stumbling block and foolishness to those who do not; that is, those who prefer rectangular planks to the form of blade which science proclaims, and nature everywhere confirms—whose ideas of driving ships over seas and rivers are those of the builders of Roman gallies, and engineers of the Middle Ages. They propelled vessels by two, four, and sometimes six oxen. Two were yoked to and traveled round a vertical shaft, and each shaft carried a pair of paddle wheels identical with those by which they ground corn on the edge of running streams, and in boats anchored on rapid rivers.

If there are other examples of non-advancement over the dark ages as gross as this we know not where to look for them. Our planet is a school for engineers, as for other professions. It is alive with illustrations of mechanical laws, as fixed and immutable as the universe

itself; and nothing is more certain, that only so far as our devices accord with them can they succeed. Thus it will be, as heretofore, with the propelling blades of a steamer as with the force that propels them. Abortive *must* be all attempts to make her speed what it ought to be as long as the principle of *form* so distinctly and variedly manifested in organisms that move rapidly through air and water is ignored. It is fundamental. No finite intelligences can improve or supersede it. There is marvellously more in it than common observation perceives. It governs other attributes. Endless are the projects on minor points, and all of them fruitless for lack of that which only can give value to any.

Every horizontal section of a blade has a different velocity, and, to make the resistance and effect uniform, its width must *diminish with the dip*. The centre of resistance, instead of being near the extremity, will then be drawn in towards the centre of the blade, and economy of force will result. There is, in fact, a reciprocal influence pervading every part, every feature and movement of a perfect blade; and wherever this harmonious action does not exist, loss of speed and waste of power are and will forever be inevitable, for physical laws are eternal. There are some things which the present state of science and the arts cannot accomplish, but there is no obstruction, mental or physical, to our giving to sea-boats a maximum of speed with a minimum of force—to our rivalling in this respect the ablest engineers of the future!

If not disgraceful, it certainly is not creditable to American and European engineers that the problem has not been solved before now. It would seem impossible for it to be much longer neglected. The present opportunity of again bringing it to the notice of the Navy Department is singularly favorable. Numerous public vessels have been sold, and more are yet to be disposed of. Out of so many, one or two might surely, and without injury to the public interest, be detailed for the purposes of experiment. The British government has experimental steamers, and much more should ours; but passing that, all that is now asked that the *Algonquin* or *Winooski*—the one which proves the fleetest in the approaching trial—be fitted with blades on the principle recommended in the Patent Office Report of 1849. It is therein demonstrated that speed is essentially affected by the *figure*, *thickness*, and *number* of the blades—that their propelling power expands and contracts with the volumes of water they displace. Ocean steamers had them of $2\frac{1}{2}$, $3\frac{1}{2}$, and even 4 inches thick, amounting to from four to five hundred cubic foot of solid timber to be kept whirling through air and water, and losing on the average 7 feet of effective stroke (the aggregate thickness of one wheel's blades) at each revolution: some wheels actually lost 12 feet of stroke at every turn. But there were engineers then who maintained the hypothesis "the thicker and heavier the blades the better, for the heavier the wheels the easier they work!"

The *length* of paddle planks then varied from 12 and 14 to 22 feet! The incessant jar arising from their striking the water was shown to be a ceaseless source of destruction to both engine and vessel, as well

as waste of power. Some boats had wheel houses wider than their decks, so as to make it doubtful to strangers to such craft whether the hulls were accessories to them or they to the hulls. In this respect the number of blades has been greatly reduced. There where then steamers with 36. The *United States*, among others, had one bolted to each side of her radial arms or levers. The number settled down to 28, next to 14, and now there are examples of only 7 being employed as urged in the Report. But the most important suggestion is yet ignored by those who have taken advantage of the rest, and, with scarcely an exception, without the slightest acknowledgment. It will, however, yet be conceded that the naked arms of old steamers wheels would, if sufficiently lengthened, have propelled them more effectually than the usual plank paddles attached, because of their approximating the only principle applicable to the case—that which nature illustrates in the long, narrow and tapered organs of her swiftest swimmers and flyers; and (as there is no originating a law or principle of our own) which, in order to succeed, we must adopt or fruitlessly oppose and fail as heretofore. Instead of churning the water's surface with wide dashers, we must take deep hold of it with blades that enter without jarring and lift no loads of it on leaving.

The usual prenomen to steamers wheels is a wrong one, there being no analogy in their action and that of the Indian's paddle. To resemble it the longer axis of the floats or buckets, instead of being parallel with the shaft, should be perpendicular to it, and instead of seeking resistance away from the hull, find it in depth close to it. The *oar* reaches out, but that is to adapt it to human power. Sweeping horizontally through the water at a much greater distance, more power is lost in being imparted to its blade than to that of the paddle. In large wheels the loss is considerable, as the power has to pass to and from the furthest ends of the buckets, whose action is really that of rotating oars—widely different from that of vertical paddles which would dispense with three-fourths of the massive overhanging shafts.

To use the narrow blades of paddles for undershot wheels would be quite as rational as employing the wide planks of the latter for propellers.

A series of experiments was proposed to the administration of President Taylor, and a vessel—the *Water Witch*—was designated for the purpose, but his sudden and lamented death put an end to the design. Conducted under the supervision of the heads of the Coast Survey and Smithsonian Institution, scientific officers of the navy and representations of the Franklin Institute, the result, whether in favor of or against the current wheel, would have been of lasting value, and so will the solution of the problem be whenever and by whomsoever it is accomplished. The government has now another reliable source of information and advice in the National Academy of Science.

In 1855, Professors Bache and Henry, in a letter to the Secretary of the Navy, stated that the proposed experiments "would be of great practical value to the world at large, and of particular advantage to the Navy of the United States." But the time for them had not come. The

28 *

reply was, "The Department appreciates very highly the importance of a series of experiments on the best form of propelling blades or paddles for producing, with a given expense of power, the greatest useful effect. It has, however, to regret the want of authority to undertake them, * * * and could not, without inconvenience to the public service, furnish a vessel for the purpose."

It may be that the Navy Department inclines to the opinion of some of its subordinates, that the paddle wheel is all that is wanted, and, so far from ever being superseded, is destined to move the earth's fleets of steamers as long as its prototypes transmits power from running streams to mills and factories. Well, why not then have a practical demonstration of its superiority, which would repay the cost a thousand fold and reflect enduring honor on the Department. The expense can hardly exceed the tithe of a tithe of the pending experiments on steamers and steam. Were it as great it would be true economy to incur it.

There is, of course, an end of the question of propulsion with those who think there is no natural law or principle of velocity in steam vessels, or, if there is, that it has no relation to the form of propelling instruments. If they are right, the highest speed has been attained, and we may sit down and rest satisfied with the common wheel, for there is no risk in repeating the assertion that nothing more is to be got out of it. After undergoing endless variations in details, its dimensions have been swelled to extreme practical limits, and to meet the resistance an unprecedented amount of metal has been put into the shafts—and to what purpose? The largest have been strained to breaking, yet no increase of speed. But it is preaching in the desert to reason with those whose ideas of progress are bounded by the present—who imagine steam fleets of the future are not to surpass those of to-day.

The sole motive in calling the attention of the government once more to the subject, is an abiding conviction of its importance to the Navy. The writer has no selfish object to accomplish—no wish to divert a dollar from the Treasury into his pocket. He has nothing to gain by the adoption of his views, and nothing to lose by their rejection. E.

NEW YORK, October 14, 1865.

For the Journal of the Franklin Institute.

Particulars of Iron Steamships.

HANSA.—Hull built and machinery constructed by Messrs. Caird & Co., Greenach, Scotland. Route of service, New York to Bremen. Commander, Captain Von Santen. Owners, North German Lloyds.

Hull.—Length at load line, 330 ft., do. over all, 360 ft. Breadth of beam, 42 ft. Depth of hold, 26 ft. 2 ins. Depth to spar-deck, 33 ft. 6 ins. Number of decks, 4. Draft at load line, 22 ft. Frame of wrought iron plates, 1 in. to $\frac{5}{8}$-in. in thickness, and fastened with rivets $1\frac{1}{4}$ and $\frac{7}{8}$-inch in diameter, and $3\frac{1}{2}$ inches apart. Floor, shape, Z; molded, 6 ins.; sided, $\frac{3}{4}$-in.; apart at centres, 18 ins. Beam ties on each deck. Bulkheads, 5. Rig, barque. Has Davidson's surface condensers. Tonnage, 2830 tons, O. M.

Engines.—Vertical direct. Number of cylinders, 2. Diameters of cylinders, 80 ins. Length of stroke of piston, 3 ft. 6 ins.

Boilers.—Five, tubular. Have water bottoms.

Propeller.—Diameter, 18 ft. Number of blades, 2. Material, cast iron.

REMARKS.—This is a magnificent steamship, well fitted in every respect, and has accommodations for 250 first and second class passengers, and 560 steerage passengers.

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GERMANIA.—Hull built and machinery constructed by Messrs. Caird & Co., Greenach, Scotland. Route of service, New York to Hamburgh. Commander, Captain H. Ehler. Owners, Hamburgh American Packet Company.

Hull.—Length on deck, 327 ft. Breadth of beam, 40 ft. Depth of hold, 25 ft. Depth to spar-deck, 33 ft. Number of decks, 4. Draft at load line, 22 ft. Frame of wrought iron plates, $\frac{3}{4}$-in. to $\frac{5}{8}$-in. in thickness, and fastened with rivets $\frac{3}{4}$-in. in diameter, and $2\frac{3}{4}$ to 3 ins. apart. Floors, shape, Z ˥ ; molded, 6 ins.; sided, $\frac{11}{16}$-in.; apart at centres, 18 ins. Wrought iron plate stringers on two decks. Main deck of iron. Bulkheads, 7. Rig, barque. Tonnage, 2552 tons, O. M.

Engines.—Vertical direct. Number of cylinders, 2. Diameter of cylinders, 72 ins. Length of stroke of piston, 4 ft.

Boilers.—Four, tubular. Have water bottoms.

Propeller.—Diameter, 16 ft. Number of blades, 2. Material, cast iron.

REMARKS.—A first-class vessel, elegantly fitted up in her cabin, saloons, &c., and a model of strength and speed.

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SCOTIA.—Hull built and machinery constructed by Messrs Robert Napier & Co., Glasgow, Scotland. Route of service, New York to Liverpool. Owners, British and North American Royal Mail Steamship Company.

Hull.—Length of keel and forerake, 360 ft. Length on deck, 374 ft. 6 in. Length over all, 400 ft. Breadth of beam, 47 ft. 8 ins. Depth of hold, 23 ft. 10 ins. Depth to spar-deck, 32 ft. 6 ins. Number of decks, 3. Draft at load line, 22 ft. 10 ins. Frame of wrought iron plates, $\frac{15}{16}$ to $\frac{11}{16}$-in. in thickness, and fastened with rivets $\frac{7}{8}$-in. in diameter, and $2\frac{3}{4}$ and $3\frac{1}{2}$ ins. apart. Floors, shape, I ; molded, 10 ins.; sided, $\frac{3}{4}$-in.; apart at centres, 21 ins. Beam ties on all decks. Bulkheads, 6. Two smoke-pipes. Rig, brig. Tonnage, 4136 tons, O. M.

Engines.—Side lever. Number of cylinders, 2. Diameter of cylinders, 100 ins. Length of stroke of piston, 12 ft.

Boilers.—Four, tubular. Have water bottoms.

Water-wheels.—Diameter, 40 ft. 8 ins. Number of blades, 28. Material, iron.

REMARKS.—The framing of the *Scotia* is constructed in a manner securing the greatest amount of strength. The framing of her bow is placed diagonally. Her keel consists of several bars of iron 35 ft. in length, each joined together by long scarps, and is, as a whole, 14 ins. deep by 5 ins. thick. The weight of the iron in this vessel, when launched was 2500 tons, and the finished weight of the hull was 2800 tons. Her masts are 2 ft. 6 ins. in diameter. E. M. B.

Recent Applications of Magnesium. By WILLIAM WHITE.

From the London British Journal of Photography, No. 280.

Last year magnesium was introduced to commerce, and since its introduction, several attempts have been made to convert it from an article of curiosity and amusement into one of utility.

At Bath, last summer, we bought it in wire, and blinded ourselves and dazzled our friends with its brilliant light shortly after it was discovered that combustion was improved by flattening the wire into ribbon, and ribbon has almost superseded wire in the shops.

Magnesium so far has almost exclusively been regarded as a source of light, and the problem is how to burn it to the best advantage.

Lamps.—Assuming that wire or ribbon was the best form, the question narrowed itself to the contrivance of some apparatus which would pay it out at the precise rate of combustion.

Invention moves by easy steps. The first attempts were made by Mr. William Mather, of Salford, and Mr. F. W. Hart, of Kingsland, London, who each produced a lamp in which the wire was delivered by hand from a reel, and guided through rollers, and a tube to the flame of a spirit-lamp, in order to avert the risk of extinction. To this lamp Mr. Alonzo Grant, of Nottingham, affixed clockwork; and with this addition it has met with considerable success.

The risk of sudden extinction was a chief difficulty in the early use of the magnesium light, probably arising from some flaw in the wire—the presence of some foreign matter in its substance. As the manufacture has improved, and the wire has assumed a degree of ductility unknown in samples a year ago, this difficulty has become greatly reduced, and especially in the case of the ribbon, which I have seen burn steadily for half an hour without sign of intermission. Perfect certainty of combustion (dispensing with the spirit-lamp) has been ensured by the use of a double strand of wire or ribbon, it being exceedingly improbable that the flame of both should go out at the same instant, and, in the event of one being extinguished, it would be relit by the other. One of Grant's lamps paying out a double strand has burned for two hours without cessation; and it is only necessary that the reels of magnesium and the clockwork be enlarged to secure a continuous light for any requisite time.

Captain Bamber, R.N., of Clarence House, Jersey, has been making a variety of experiments in order to adapt magnesium to common use in mines, tunnels, and railways. His instrument consists of a mahogony box, about eighteen inches long, containing a series of small wheels (much resembling those of a musical box), and a drum, round which the wire is wound, and from which the burner is supplied at a rate proportionate to the revolution of the drum, whose action is governed by a regulator. The burner is enclosed by a powerful lens or "bull's eye." Captain Bamber exhibited this instrument one night lately at the Paddington Railway Station, and though the thinnest ribbon manufactured was used, the time was easily read off a watch at the distance of 250 yards.

Something yet wanted.—There is manifestly much more to be accomplished in the matter of lamps. We require apparatus whereby a hall or picture gallery can be illuminated for the evening. This, one would say, should be effected by burning the magnesium overhead from the centre of the ceiling, but the disposal of the smoke and ash, consisting of pure magnesia, is the difficulty—a difficulty, however,

which has only to be stated to be met and overcome. Already some ingenious mechanics are tackling it hopefully.

Magnesium Filings.—It is a question whether magnesium in filings has met with due attention. It would not be difficult to deliver a stream of metal as sand from an hour-glass into a jet of gas or other flame, and thus maintain a light with a certainty equal to that obtained by wire and clockwork.

Cui Bono?—"A very curious and beautiful light; but what is the good of it?" asks the practical man. As Franklin met a similar question in the case of electricity, "What is the good of a baby?" Magnesium is a baby, yet though a baby, it has already given some pledges of its manhood. One of its first feats was taking a number of portraits at night with a precision and effect equal to sun-light. This done, it was at once suggested, Why may we not have photographs of caves, catacombs, crypts, mines, and of every dark and wonderful cavity?

Professor C. Piazzi Smyth.—One of the first to put this suggestion to the test was the Scottish Astronomer Royal. Probably all have heard something of the interesting controversy connected with the granite coffer—the *sanctum sanctorum* of the Great Pyramid. It was Professor Piazzi Smyth's great object to bring this mysterious coffer to light, and to dissipate forever all uncertainty about it. This, with the aid of magnesium, he has accomplished. We shall shortly have a volume from his pen descriptive of his researches and conclusions, and illustrated with photographs. Meanwhile he has most kindly allowed copies of his photographs to be exhibited to the Association, and has favored me with a few notes concerning them, which I shall now read:

"*Photography in the Great Pyramid.*—1st. The interior of the Great Pyramid did not prove a good space for developing the excellencies of the magnesium light. The ventillating passages opened by Colonel Howard Vyse in 1837, have been completely stopped up with stones and sand by the Arabs. Hence the air in the interior of the Pyramid has no visible means of being changed or purified, and as the said interior is visited every day through six months in the year by numerous parties of visitors bearing candles, the oxygen is so deficient, and the carbonic acid so abundant, that my surprise is that the magnesium burnt at all. It did burn, but in a languid sort of way, and the smoke it threw off remained suspended in the motionless air for twenty hours or more, so that only one picture could be taken in twenty-four hours. If a second was attempted, the illuminated smoky air intervening between the camera and the object desired to be pictured was the only result on the photographic plate.

"2d. My object was not pictorial or artistic photography (of which I have therefore nothing to show), but the application of photography to certain disputed and special parts of the interior of the Pyramid for the sake of scientific examination and measurement; and those objects *were* obtained, notwithstanding all the drawbacks of the place, which really seemed combined to frustrate the merit of the light.

"3d. One example or success is presented in the granite coffer, in

the king's chamber of the Great Pyramid. According to the theory of the late Mr. Taylor, that coffer was a primeval measure of capacity, from whence is derived the hereditary Anglo-Saxon wheat measure, called the quarter, of which coffer it is the fourth part. Whilst, however, we know by Act of Parliament how many cubic inches are contained in four quarters, English, there has been much doubt as to the cubical contents of the granite chest of the Pyramid. The measures of the French Academy, in 1799, made it 6300 cubic inches greater than several English travelers had declared it to be, though they again by no means agreed with each other in subsidiary details. Now, however, by means of the magnesium light, we have a series of photographs of this coffer, with a system of measuring rods fastened about it,* showing the inside and the size outside, and, finally, the cubical contents being summed up, prove that the remarkable granite vessel *is* a measure of capacity, equal, with almost mathematical accuracy, to four quarters, English."

A Revealer of Colors.—A peculiarity of the magnesium light is that it leaves colors unaffected; that is, it displays them as in sunshine. This may be verified with agreeable effect by burning a piece of wire at night in a garden or conservatory, when it will be found that greens and blues, yellows and whites, reds, violets, and purples appear with perfect distinctness. This fortunate quality has led to the employment of the light by dyers and silk mercers as a ready means of settling questions as to shades of colors, either at night or in foggy weather.

Alloys.—A variety of magnesium alloys has been made, but none so far with any obvious excellence. Some experimentalists have had trouble in preventing the combustion of the molten magnesium. An easy way of getting over this difficulty is by first melting, say the copper, and then with pincers or otherwise holding the piece of magnesium underneath its surface until it is dissolved. By practiced and dexterous handling, molten magnesium is safely managed in closed vessels, but any one may try his hand at alloys by the method described.

An alloy of lead and magnesium burns very well; but the best combustible result is obtained by the combination of zinc and magnesium. Alloys with zinc in the proportions of 5, 10, 15, and 20 *per cent.* are readily converted into wire, and burn steadily, giving out more smoke however, and the light exhibiting less actinic power.

For common pyrotechnic purposes these combinations of zinc and magnesium promises admirably. Reduced to powder they supply a brilliant ingredient for rockets; and in the shape of wire, they form a simple and efficient firework, cheaper, if less dazzling, than magnesium alone, and quite worthy of Guy Fawkes' day.

Captain Bolton's Opinions and Experiments.—To the utilization of magnesium no one has brought such experience and such resources as Captain Bolton. As is well known, he devised the oxyhydrogen signal

* The application of the measuring rods was a happy idea worked out by Joseph Sidebotham, Esq., of Manchester. He supplied Professor Piazzi Smyth with some large slices of an old organ pipe of Queen Anne's time, as the most unexceptionable stuff—thoroughly seasoned wood wherewith to make trustworthy scales.

apparatus introduced to H. M.'s service some three years ago. The credit attached to this success would have tempted many a man into the position of an obstructive, but Captain Bolton having arrived at the conviction, based upon actual experiment, that the magnesium light possessed all the necessary attributes for a perfect naval and military signal light, equally with the electric and lime light, and with decided superiority over them in the grand requisite of handiness, he at once avowed his conviction, and set to work to apply its powers to the best advantage.

In the first place, in conjunction with Captain Colomb, he has succeeded in introducing magnesium powder into signal lights for use in the mercantile marine. These lights are intended to burn on the port or starboard sides of vessels entering port during thick or foggy weather. They last 3, 5, or 8 minutes, and longer lights from 12 to 15, and are distinctly visible at a distance of eight miles. The cost is trifling.

The Mercantile Marine Association of Liverpool, have lately recommended that a powerful red light be made as the signal for danger at night. This recommendation Captain Bolton and Captain Colomb have met, again, by the use of magnesium in powder. They have prepared a red light to burn about 15 minutes at a cost of 1s. 6d. It is visible in clear weather at a distance of 10 miles. The signal is now under consideration by the Association.

A greater interest, however, belongs to Captain Bolton's efforts to supersede the oxyhydrogen light by the combustion of magnesium in simplicity, in wire or ribbon. His apparatus for this purpose is not yet complete, and until it is it would be unfair to him to prejudice it by description. Suffice it to say, that he has succeeded in consuming or suppressing the smoke, and with a few more adjustments will accomplish clipping off the ash which gathers on the point of the burning strand of magnesium, and sadly dims its glory.

With all imperfections, Captain Bolton has found it easy to signal with magnesium from Shoeburyness to the Great Eastern, eight miles off; and from Portsmouth to St. Catharine's Downs, Isle of Wight, a distance of sixteen miles.

Supposing Captain Bolton should fully attain what he purposes, it will lead to the employment of magnesium in all the ships and lighthouses of Europe. Rid magnesium of its smoke and ash, and there is no light to compare with it in other respects.

Magnesium in America.—The manufacture of magnesium has been commenced in Boston, and from the men in Massachusetts, who are said as babies to lie awake and scheme improvements and patents in the construction of cradles, we are likely to hear of some novel applications of the metal. If the contest in which they were engaged had not so happily ended, we should have learned ere this a good deal about the utility of magnesium in war. We were startled last February in *The Times* and other papers, that blockade-running was about to receive an unexpected check, for it had been found possible to remove the veil of night by the blaze of magnesium fire. In a rough way it

may be said, that to us in England novelty is a prejudice to be overcome, but to Americans, novelty is a recommendation.

Other Uses for Magnesium.—All our talk has been of magnesium as a source of light, but surely it will be found capable of other applications. It is, perhaps, the most abundant metal in nature. It rolls in the sea, and forms vast tracks of land. If, as some say, everything in creation bears reference to man, and was designed for his use, what a future there is for magnesium! Sir Humphrey Davy was the first to give the hint of its existence, nearly sixty years ago; it is time that Birmingham converted that hint to practical purpose.

On Chemistry Applied to the Arts. By Dr. F. CRACE CALVERT, F.R.S., F.C.S.

From the London Chemical News, No. 247.

(Continued from page 248.)

LECTURE V.*

BILE, its properties. *Blood*, its composition and application in the refining of sugar and manufacture of Albumen. *Albumen*, its application to calico printing and photography. *Milk*, its composition, properties, falsification, and preservation. *Urine*, its uses. A few words on putrefaction.

In this lecture we shall examine the composition of the various liquids secreted in the human body and in those of animals, and the uses to which these fluids are applied in arts and manufactures.

Bile.—The composition and appearance of bile vary greatly in different animals. Usually it is a yellow, green, or brown thick fluid, with a marked alkaline reaction, and containing about 14 per cent. of solid matter, the most important constituents of which are, in human bile, mucus, two coloring matters, one yellow, (*cholepyrrhine*,) the other green, (*biliverdine*,) sugar, albumen, two organic acids, (*cholic and choleic*,) combined with soda, oleate and margarate of soda, a non-saponifiable fatty matter, (*cholesterine*,) and several mineral salts. The two most interesting substances in bile are choleic acid and cholesterine, which, when produced in undue proportion, give rise to those calculi, the passage of which through the biliary duct is so dangerous and painful. One of the most valuable papers published of late is that of Mr. G. Kemp, in the *Transactions* of the Royal Society, on the conversion of the hepatic bile into cestic; thus he has shown that as the former is secreted by the liver, and arrives by the biliary duct into the gall bladder, it is there converted into cestic bile by means of a special fermentation induced by a mucus secreted in the walls of the gall bladder. It is believed by most physiologists that the principle function of bile is to neutralize the acid fluids resulting from digestion in the stomach, as they enter the small intestines, rendering them better adapted for their sojourn there, and also facilitating their fermenta-

* This lecture was No. VI. when the course was delivered, but the present order of publication has been adopted, as bringing the whole subject more systematically before the reader.

tion, one of the most important phenomena of digestion. The employment of bile as a scouring agent has much diminished of late years, owing to the substitution for it of benzine and Sherwood spirit.

Blood.—The study of this all-important fluid is most interesting in a physiological point of view, for the twenty-seven pounds of blood (the average amount in an adult) which travels through the whole of the human frame in about three minutes, fulfils three distinct functions, viz: it carries the various elements of food, as modified by digestion, into the different parts of the body requiring them; it helps to remove from the system those substances which have fulfilled their required functions in it, and which have been rendered useless by the wear and tear of life; and it conveys through the system the heat generated by the oxidation, through respiration, of the substances which have been absorbed during digestion, as well as those which have performed their part in the human economy, and require to be removed therefrom. It will, therefore, be easily understood that blood must be a complicated fluid; and the following table will give an idea of the truth of this assertion:

1000 parts of blood.

130·85 of clot.	Fibrine,	2·95	130·85
	Globules,	125·63	
	Hematosine,	2·27	
869·15 of serum.	Water,	790·37	869·15
	Albumen, Soda,	67·80	
	Phosphate of Soda,	10·98	
	Lactate of Soda,		
	Carbonate of Soda,		
	Chloride of Sodium,		
	" of Potassium,		
	Carbonate of Lime,		
	" of Magnesia,		
	Ammoniacal Salts,		
	Phosphate of Lime,		
	" of Magnesia,		
	Sulphate of Potash,		
	Fatty Acids, free or combined,		
	Cholesterine,		
	Lecithine (phosphuretted fat),		
1000·00	Ceribrine, or nitrogenated fat,		1000·00

It will facilitate our study of this complicated fluid if we class the various compounds existing in it under six different heads. First, if blood, immediately after being drawn from an animal, is whipped with a birch rod, the ends of the twigs will have hanging from them a stringy mass, which, after being well washed, is grey and elastic, and is called *fibrine.* Secondly, if the blood so treated is mixed with a solution of sulphate of soda of specific gravity 1·16, and the whole thrown on a filter, the *corpuscles* and the coloring matter called *hematosine* will remain on the filter, and these substances with the fibrine form, as shown in the table, the clot of blood. Further, if the matter left on the filter is treated with concentrated acetic acid, the coloring matter is dissolved, and the corpuscles are left as yellow discs. Thirdly, on boiling the fluid which passes through the filter, albumen is coagulated

and can be easily separated, leaving water and a few saline substances which are easily separated by evaporating the liquid portion. Allow me now to add a few remarks on some of the substances above mentioned. Fibrine represents the fibrous or muscular part of animals, but has no direct application in manufactures. The blood corpuscles in man are ellipsoid discs, containing the coloring matter of blood. The most interesting fact connected with the latter is that it is united with a compound containing iron; and although iron does not appear to be an integral part of the color, still its presence appears essential to the existence of the color itself. The external part of the discs is composed of fibrine, whilst the interior contains an albuminous fluid, (which differs from the albumen of the serum in the fact that it is not coagulated by heat,) and which is called globuline. The relative proportion of fibrine, globuline, and hematosine vary considerably in different individuals, according to health, age, and sex, and even during the process of digestion. When blood is examined under the microscope, large colorless globules are found to float with those just described. Dr. William Roberts, of Manchester, who has examined the corpuscles of blood, has observed that when they are dipped into a solution of magenta, they assume not only a pink color, but that the nucleus of the disc acquires a much deeper shade. Further, that on the sides of the disc there are small projections which he calls pullulations, and which acquire a much deeper tint than the remainder of the discs when plunged into the magenta solution. Another curious fact lately observed by M. Pasteur is that if blood is kept for several weeks in a cold situation, air being excluded, the corpuscles disappear, and are replaced by myriads of beautiful red well defined crystals. Lastly, there is a slight difference of composition between arterial and venous blood.

	Arterial.	Venous.
Carbon,	50·2	55·7
Nitrogen,	16·3	16·2
Hydrogen,	6·6	6·4
Oxygen,	26·3	21·7
	99·4	100·0

It is strange that, while blood is so extensively employed on the Continent, in various branches of manufacture, that in Paris 2000 tons of blood are used by sugar refiners alone, hardly any such application of this fluid is made in our own country. It appears to me that the explanation is to be found in the fact that on the Continent beasts are generally slaughtered in public abattoirs, by which means many of the refuse matters can be collected with advantage, and without being spoilt or polluted by unscrupulous persons, whilst in this country, where animals are slaughtered in innumerable private slaughter houses, the difficulty and expense of collection, together with the absence of guarantee of quality, render the successful use of blood on a large scale impracticable. There is an additional advantage in the system of public abattoirs, which I cannot help noticing *en passant*, viz: the guarantee thereby obtained that the public food is not furnished from

diseased animals. The only employment of blood in its integrity in this country is as an article of diet, and to some extent in the manufacture of prussiate of potash. The serum of blood is sometimes used in England, as well as on the Continent, as one of the substances essential in the process followed to communicate to cotton the magnificent color called "Turkey red."

Albumen, (blood.)—The employment of this substance in the art of calico printing is of comparatively recent date, as it is chiefly due to the introduction of the tar colors and pigment styles into that art. To fix colors with this albumen (or that of egg) it is only necessary to dissolve in a gallon of water several pounds of albumen and gum Senegal, adding a little tar color, such as magenta, &c., or a pigment, such as ultramarine blue; these mixtures are then printed on the cotton fabric, and the color fixed by the coagulation of the albumen under the influence of high pressure steam. But the quantity of albumen used for this purpose has greatly decreased of late years, owing to the introduction of tannin by Mr. Charles Lowe and myself, Messrs. Roberts, Dale & Co., and Mr. Gratrix, and also that of the arseniate of alumina by Mr. W. A. Perkin. The substitution of blood albumen for that of egg is chiefly due to Messrs. Robart, Roger & Co., who, I believe, prepare it by separating carefully the serum of blood from the clot, adding to it a small quantity of alum to separate any coloring matter that may be mixed with it, and evaporating the water of the serum by a current of air heated to 100°, which leaves the albumen in the form of yellowish scales, freely soluble when placed again in contact with water. The most abundant source of albumen, however, is the white of egg, and, therefore, let us glance at a few facts connected with this substance, doubly important as an article of manufacture and as one of food. To give some idea of the extensive use of eggs, I may state that in Paris there are annually consumed 178,000,000 eggs, weighing 28,000,000 lbs. The composition of a hen's egg may be stated as follows:

Shell,	11·5
White,	58·5
Yolk,	30·0
	100·0

The following are the respective compositions of the yolk and white:

Yolk.	
Water,	51·47
Vitelline,	15·76
Oleine, Margarine, Cholesterine,	28·97
Phospho-glyceric acid,	1·26
Coloring matters,	1·20
Mineral salts,	1·34
	100·00

White.	
Water,	86·34
Albumen,	12·50
Membrane,	0·50
Phosphates, Chlorides, &c.,	0·66
	100·00

An egg may be considered as consisting of four parts, the shell, membrane, white, and yolk. The shell is composed of carbonates of lime and

magnesia, phosphate of lime, and oxide of iron, the whole bound together by a nitro-sulphuretted substance. The presence of sulphur in this substance, as well as in albumen, explains why eggs give off sulphuretted hydrogen when boiled. The membrane lining the shell is also a nitro-sulphuretted substance, much resembling in its composition that of horn. I have already had occasion to speak of the interesting composition of the yolk of egg, when mentioning its application in the glove manufacture, and on that occasion I drew your attention to the remarkable substance called vitelline, and to the peculiar nature of the fats contained in yolk of eggs, but more especially to the phospho-glyceric acid, and attributing to them the peculiar properties imparted to leather through their use. The white of egg chiefly consists, as the above table shows, of a substance called albumen, which you will remember is found in blood, and I may add that it exists in the sap of all plants. Albumen is a fluid of an alkaline reaction, soluble in water, and coagulates at 160 degrees when undiluted, but when dissolved in water the temperature at which it coagulates is raised according to the extent of its dilution. Albumen gives a precipitate with all metallic salts, but one of the most characteristic and delicate tests for albumen in solution is bichloride of mercury or corrosive sublimate. In fact, albumen is the best antidote known to the action of this violent poison when taken internally, as was proved by its saving the life of an eminent chemist (Baron Thenard) in 1825. All acids, except phosphoric and acetic, precipitate albumen from its solutions, but that which separates it with the greatest nicety is nitric acid; when placed in contact with hydrochloric acid for a few hours, it assumes a very beautiful purple color. When albumen is placed in shallow vessels, and then stored in a chamber where air at 100° is allowed to circulate, the water evaporates and leaves the solid albumen in the form of yellowish, semi-transparent scales, which, strange to say, will, if kept dry, resist putrefaction for any length of time, although in its liquid form the large amount of nitrogen it contains renders it highly putrescible. It is this solid albumen which is used by calico printers, as it is easily dissolved in water, and rendered applicable to their purposes. Albumen is often used in manufactures to clarify fluids. In some instances the albumen in solution is added to the fluid and carried to the boil, when the dissolved albumen coagulates, and in falling through the fluid carries with it mechanically the matters in suspension, when it is only necessary to decant the clarified fluid. In others it is added at natural temperature, as in the case of wines, where the tannin, alcohol, and acids are the agents which coagulate the albumen. Albumen was first applied to photography by Niepce de St. Victor, in the following form: He mixed together intimately ten fluid ounces of distilled water with the white of ten fresh eggs; to this he added 200 grains of chloride of sodium or chloride of ammonium. The whole was well shaken in a bottle for about ten minutes, and then allowed to stand. All that was then required was to decant the clear liquor, and apply it to the surface intended to receive the photographic image. (Here the lecturer shortly described this photographic process,

and alluded to the recent application of the light resulting from the combustion of magnesium wire, manufactured by Messrs. J. Mellor & Co., of Salford, showing its applicability to photography by using this light to take photographs during the lecture, stating that the cost was only a few pence.) A great many attempts have been made to preserve eggs from decay, the most successful of which have been those of Le Maison Cormier du Mans, who covers the eggs with an impermeable varnish, packing them in sawdust, so that the egg shall always rest on one end. Another process is that of immersing the eggs in lime water. Lastly, the whole of the egg has been emptied out of the shell and evaporated to a solid mass. I must not conclude the subject of the albuminous and vitelline substances without calling your attention to the following table, which will give an idea of the different albumens and vitellines which Mr. E. Fremy has succeeded in isolating and characterizing:

Eggs of Birds.

Albumen	coagulated by heat,	All these substances are characterised by containing sulphur.
Eudophacine	" " "	
Albumen	" " "	
Meta Albumen	" " "	
Exophacine	" " "	

Eggs of Fishes.

Ray,	Ichthine,	All these substances are characterised by containing phosphorus.
Goldfish, Carp,	Ichthidine,	
Salmon,	Icthuline and Salmonic acid,	
Turtle,	Eurydine.	

(To be continued.)

On the Supposed Nature of Air prior to the Discovery of Oxygen.

By George F. Rodwell, F.C.S.

From the London Chemical News, No. 237.

Continued from page 254.

XIII. Boyle's Second Pneumatical Treatise.—It will be remembered that Boyle's first series of "Physico-Mechanical Experiments Touching the Air" appeared in 1660. In 1661 he presented his air pump to the Royal Society, and during the five following years he undertook no lengthy pneumatical research. Occasionally, however, during this period we find mention of vacuum experiments shown by him at meetings of the Royal Society;* but now that the air pump had passed out of his possession, it is obvious that he had not the same facilities as before for carrying out a research of any magnitude.

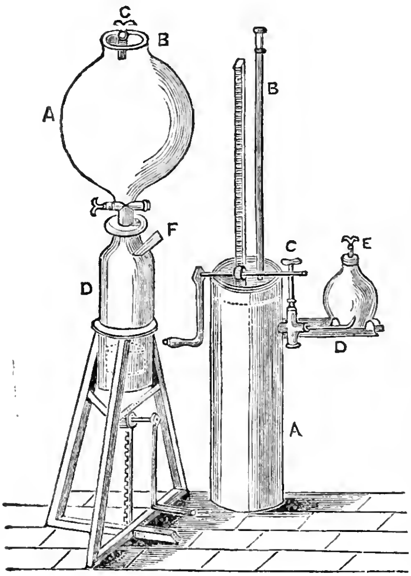
Inasmuch as during these five years Boyle heard of only two air pumps having been constructed, and of only one or two new vacuum experiments, he determined to construct a new air pump, and to proceed further with his former experiments. With the assistance of Hooke he constructed an air pump in 1666, of different form from the first one, and in some respects superior to it. In order that the two

* These experiments have been detailed in the preceding paper.

may be compared, we have placed them side by side in the accompanying wood cut. Fig. 1 represents the instrument constructed in 1659, which was employed for the first series of experiments (described in the fourth and fifth of these papers); Fig. 2, the second air pump constructed in 1666, and employed for the experiments detailed below.

A (Fig. 1) represents the receiver, a globe of glass of the very large capacity of "thirty wine quarts;" it had a circular opening above, into which was cemented a brass ring B, closed by an accurately turned disc of brass, which fitted into it, and could be readily removed for the introduction of objects to be experimented upon. The disc was perforated, and the orifice closed by a ground brass stopper C, by turning which, bodies within the receiver connected with it by a string could be moved when the receiver was exhausted. The lower part of the receiver communicated directly with the cylinder D, and was furnished with a stopcock E. A solid piston moved by a rack and pinion, worked within the cylinder. In the upper part of the cylinder there was an orifice, into which the brass stopper F, fitted air tight; this served as a valve. Suppose the piston at the top of the cylinder, the stopper F, in its place, and the stopcock E, closed, the piston is drawn to the bottom of the cylinder, (that is to say, to the position shown in the figure,) and E is opened; immediately part of the air in the receiver rushes into the vacuous space in the cylinder; E is then closed so as to shut off communication between the cylinder and receiver F is removed, and the piston forced to the top of the cylinder, the air within the latter escaping through the valve orifice; F is now replaced, and the previous operation repeated until the receiver is exhausted.

Fig. 1. Fig. 2.



A (Fig. 2) represents a cylinder of metal, furnished with a piston moved by rack and pinion. The valve (F, Fig. 1,) of the 1659 air pump was in this transferred to the piston, which was perforated, and the orifice was closed by a brass stopper with a long handle B, for the purpose of placing it in the orifice when the piston was at the bottom of the cylinder. A pipe, provided with a stopcock C, issued from the side of the cylinder, and, passing along the air pump plate D, terminated beneath the receiver E. The piston being at the bottom of the cylinder, the stopper in its place, and the stopcock C closed, the piston is raised to the position shown in the figure, and C is opened; immedi-

ately air from the receiver flows into the vacuous space in the cylinder; C is now closed, the valve opened by raising B, and the piston forced to the bottom of the cylinder. The stopper is then replaced, and the previous operation repeated until the desired effect is produced.

The advantages of Boyle's second air pump over the first were (*a*) the diminished size of the receiver as compared with the pump barrel, whereby the exhaustion was rendered more complete, and was more quickly obtained; and (*b*) the introduction of an air pump plate, whereby the use of a globular receiver was avoided, and bodies to be experimented upon, instead of being suspended, could be placed upon a level surface, and thus during the working of the instrument did not multiply its smallest motion by swinging, as was the case when supension was resorted to. The air pump plate was of iron, and the receiver was cemented to it, by which means Boyle managed to retain a receiver well exhausted for a length of time. The vacuum produced by the second pump appears to have been very good, of which we shall have several opportunities of judging as we proceed; the chance of leakage, moreover, was less than in the first pump. Nevertheless, the 1666 instrument had its disadvantages; like its predecessor, it fell short of Otto Guericke's pump in one respect—the valves were worked by the hand, which rendered the operation of pumping comparatively slow; it was also inferior to the 1659 air pump in one respect—the pump barrel was placed in a vessel of water, and the piston always worked under water, which not only rendered the instrument cumbersome, but not unfrequently led to water finding its way into the receiver. In describing his first air pump, Boyle mentions as a special reason why he endeavored to construct an instrument different from Otto Guericke's, that he desired to avoid the necessity of having it work under water. It is curious, therefore, that in this second pump, after further experience, he adopts that which he had previously considered so great a disadvantage.

In 1669 Boyle published a volume* containing an account of his new air pump, and of a number of experiments made therewith. It is written in the form of a letter, and is dated March 24, 1667. This second pneumatic treatise cannot be read with the same amount of interest as the first, for there is not only less original matter, but many of the experiments are mere repetitions of those described in the former treatise, and for the most part tend to strengthen results previously obtained, and to prove or disprove conjectures; but be it remembered we depreciate this work only as compared with the first treatise, for no research on pneumatics comparable to it had appeared since the first research of the same author, which excelled it.

We will briefly consider the more important experiments described in the second treatise:

* "A continuation of new experiments, physico-mechanical, touching the spring and weight of the air, and their effects. Part 1. By the Honble. Robert Boyle, F.R.S. Oxford, 1669."—Although dated 1669, this work was published in the latter part of 1668, as appears from the copy in possession of the Royal Society, on the title page of which is written. "Presented from ye author to ye R. Society, Novemb. 30, 1668."

Experiment 1.—A phial of about five ounces capacity was partially filled with mercury; a tube four feet long open at both ends was then cemented air-tight into its neck in such a manner that it reached nearly to the bottom of the phial, and consequently passed beneath the surface of the mercury; it is obvious that when the air within the phial expands, it must cause the mercury to rise in the tube. The arrangement was placed under a tall receiver, which was exhausted. When the air vessel was very large, the mercury rose no higher than twenty-nine inches, (Experiment 2;) neither did variations in the diameter of the tube alter the case, (Experiment 3.)

Experiment 4.—Water was substituted for mercury in the above arrangement; on exhausting, it was ejected forcibly from the top of the tube by the expansion of the air in the phial, the "fountain in vacuo" of our present works on pneumatics.

Experiment 8.—A bladder one-fourth filled with air was securely closed, and introduced into a receiver; it was loaded with a weight of 28 lbs.; on exhausting, the expansion of the air within the bladder raised the weight.

Experiment 11.—A tube 50 inches long was bent at a right angle; its upper portion was placed in air-tight connexion with the receiver, while its lower end dipped into a vessel of mercury; on exhausting, mercury rose to a height of 29 inches in the tube. This arrangement was afterwards applied by Hauksbee to measure the degree of rarefaction obtaining in a receiver, and is now known as the "barometer gauge."

Experiment 12.—In order to prove that the height to which a liquid is raised in a vacuous tube, by the pressure of the external air, depends upon the specific gravity of the liquid, Boyle procured a glass U tube, the length of each limb of which was 42 inches; it was inverted, one limb was caused to dip into mercury, the other into water, and the upper part of the tube was placed in connexion with the receiver; on exhausting until the water had risen to a height of 42 inches, the mercury in the other limb was found to have risen 3 inches; when strong brine was substituted for mercury, the brine column stood at 40 inches, a solution of potash stood at 30 inches, the water column being in each case at 42 inches.

Experiment 13.—Into a pint bottle Boyle poured mercury and water, so that they together partially filled it; two upright tubes, open at each end, were then cemented side by side into the neck of the bottle; one reached beneath the mercury surface, and the other beneath the water surface; the arrangement was placed under a receiver; on exhausting, it was found that when the elasticity of the air in the phial had raised the mercury to a height of 1 inch in the one tube, the water had risen to a height of nearly 14 inches in the other; when the mercury was at 2 inches, the water was at nearly 28 inches.

Experiment 14.—A short tube closed at one end was filled with mercury, and inverted into a vessel of mercury; a longer tube was filled with water, and inverted into a vessel of water; both vessels with their tubes were placed under a tall receiver; on exhausting, it was found

that when the mercury in the tube had fallen to within 3 inches of the stagnant mercury, the water column stood at 42 inches; with the mercury at 2 inches and 1 inch respectively, the water fell to 28 and 14 inches.

Experiment 15.—In order to determine the exact height to which water can be raised by a suction pump, the air pump was conveyed to the roof of a house, and a tube bent twice at a right angle was placed in air-tight connexion with the receiver. The longer limb of the tube was 35 feet long, and its lower end was caused to dip into a vessel of water standing on the ground. On exhausting, the water rose to a height of $33\frac{1}{2}$ feet, the mercury column in a barometer standing at 29 inches. This experiment, together with several of the above, prove the great efficiency of the 1666 air pump.

Experiment 16.—In order to ascertain whether air contributes to the elasticity of solid bodies, a piece of whalebone, having a weight attached to one end of it, was placed in the receiver in such a manner that it supported the weight just above the air pump plate. On exhausting, no alteration in the weight was observable.

In the 17th experiment Boyle describes the way he adopted to determine the degree of exhaustion of a receiver. In his first attempts he placed a securely closed bladder containing a small quantity of air in the receiver to be exhausted, and considered the exhaustion good when the bladder was fully inflated. He afterwards measured the exhaustion by a small U tube, closed at one end, which was filled with mercury, and a small bubble of air then passed into the closed end. The tube was placed into a vessel to be exhausted, and the rarefaction judged of by the expansion of the bubble of air.

Experiment 18.—"About an easie way to make the pressure of the air sensible to the touch of those who doubt it." In order to effect this, Boyle constructed a small brass receiver of the form of a truncated cone, open above and below; the upper orifice was $1\frac{1}{4}$ inch diameter, and the lower, which stood on the air pump plate, $2\frac{1}{2}$ inches. "The person," he writes, "that would not believe the pressure of the air to be near so considerable as was represented, was bidden to lay the palm of his hand upon the upper orifice, and being ordered to lean a little upon it, that so the lower part of his hand might prove a close cover to the receiver, one exsuction of the air was made by help of the pump, and then upon the withdrawing of the greatest part of the pressure of the internal air, that before counterbalanced that of the external, the hand being left alone to support the weight of the ambient air, would be pressed inwards so forcibly that, though the stronger sort of men were able (though not without much adoe) to take off their hands, yet the weaker sort of tryers could not do it, (especially if by a second suck the little receiver were better exhausted,) but were fain to stay for the return of air into the receiver to assist them."

Experiment 31.—A magnet was loaded with the utmost weight it could carry. It was then introduced into a receiver. On exhausting, the weight still continued to be supported.

Experiment 32.—A small brass syringe was taken, and the piston

forced to the bottom of it; the orifice of the syringe was then closed securely. When the piston was raised, great resistance was felt, and on releasing it the pressure of the air of course caused it to return to its former position. It was now placed in a receiver, and the piston handle placed in communication with the stopper of the receiver by a piece of string, so that by turning the stopper the string was shortened, and the piston consequently raised; when the receiver was exhausted, the piston was easily raised to the top of the syringe, when it was kept in that piston, and air admitted; the piston was immediately impelled to the bottom of the syringe, and the string which held it was broken. The above experiment was varied by suspending a closed syringe in the air pump receiver by its piston rod, and attaching a weight to the barrel not sufficient to draw it down—in other words, not sufficient to overcome the pressure of the air on the area of the piston. On exhausting, the barrel immediately descended, and when air was admitted, it rose to its former position, dragging up the weight with it.

Experiment 34.—A syringe was placed in a receiver in such a manner that its piston could be raised when the receiver was exhausted; a glass tube was fitted to its nozzle, and its lower orifice caused to dip into mercury. On exhausting and raising the piston, the mercury was observed not to follow it, but when air was admitted, it immediately rose to the piston.

Experiment 35.—A cupping glass was attached to the palm of a person's hand by the usual method; the hand was then made to act as a cover to a small receiver. On exhausting, the cupping glass fell down.

Experiment 40.—Some small feathers were detached from the top of a tall receiver; before exhaustion they fell slowly, and wavered in their course; after exhausting the receiver, they fell "like a dead weight."

Experiment 43.—Sugar was submitted to friction in an exhausted receiver, and was found to emit light as readily as in air.

Experiment 45.—In order to ascertain whether heat could be produced by friction in an exhausted receiver, a concave piece of brass was fixed to the air pump plate, a convex piece of the same metal was connected with a rod which passed air-tight through the cover of the receiver, and could be turned by a handle. When the two surfaces were rubbed together in vacuo, a considerable amount of heat was found to be produced.

Experiment 48.—Quicklime was slaked in an exhausted receiver, and heat was found to be produced as readily as when it was slaked in air.

With this experiment we conclude our notice of Boyle's second pneumatical treatise. There are altogether fifty experiments. Of these we have noticed the most important, omitting those which are only slightly modified forms of experiments described in the former treatise.

Moving Photographic Figures. By A. Claudet, F.R.S.

Illustrating *some phenomena of vision connected with the combination of the stereoscope and the phenakitiscope by means of photography.*

From the British Journal of Photography, No. 280.

From the beginning of photography it must have struck many of those who were acquainted with the phenomenon illustrated by the phenakitiscope invented by Plateau, that photography could produce with advantage the series of pictures used in that instrument, on account of their possessing a greater degree of accuracy than when made by hand. At a later period, when the stereoscope had become popular from its application to photography, there must have been a still stronger incitement to make use of that process to produce binocular pictures for the phenakitiscope, in order to combine the stereoscopic effect to the illusion of moving figures elicited in the phenakitiscope. For example: If a number of binocular photographic pictures were taken of a machine in various consecutive stages of its motion, these pictures, applied to a phenakitiscope, would give a complete illusion of the machine in perfect relief and in its full action.

Binocular pictures of persons dancing, fencing, or boxing, of acrobats at their wonderful feats, of boys playing at different games, all in the various stages of the action of each sport, representing consecutively the whole performance—such pictures might have been supposed to be invaluable to exhibit the stereoscopic illusion of persons in the real action of life. Therefore, the solution of such an interesting problem was capable of exerting the emulation and the ambition of many ingenious and scientific minds.

Among those who undertook the task, M. Duboscq, the eminent optician, of Paris, was the one who attained the greatest success. He had fixed the two series of binocular photographs on two zones of the revolving disk of the phenakitiscope one above the other, and by means of two small mirrors, placed each respectively at the inclination capable of reflecting the two zones, on the same horizontal line, from whence the images could each separately meet the axes of each of the two prismatic lenses of the stereoscope, each eye, during the revolution of the disk, had separately the perception of one of the series of photographs, each showing the perspective of one eye, and the stereoscopic effect of figures in motion was consequent.

M. Duboscq gave another form to the phenakitiscope. Instead of the vertical original revolving disk of Plateau, he employed a cylinder revolving on its vertical axis, and he placed on two inside zones of that cylinder, one above the other, the two series of photographic pictures between the slits through which the eyes can see the pictures, and by means of two mirrors, as in the other apparatus, each series was reflected on its respective lens through the cylinder, and the stereoscopic effect was produced in combination with the phenakitiscopic effect.

However, these two attempts of M. Duboscq did present a few imperfections, which we are going to explain. In the revolving disk the two series of pictures do not move with the same velocity, on account of their being placed on two zones of different peripheries, and this

produces a sort of confusion and distortion in the representation of the object during its movement. The same defect exists in Plateau's phenakitiscope from the perception of its single series for the top and bottom parts of the figures (owing to the cause explained), revolving in different velocities, not being impressed on the retinæ during the same time, and the blank spaces between the pictures, being larger for the top than for the bottom part, giving a stronger sensation of void during the visual perception of the pictures.

In the revolving cylinder this defect does not occur, but the picture, being considerably curved like the cylinder, is a most unfavorable disposition for examining them in the stereoscope. However, M. Duboscq's contrivances are very ingenious, and in his attempt he succeeded, at all events, in proving the possibility of solving the problem.

About that time I had also turned my attention to the subject, and found some difficulty in obtaining at once the phenakitiscopic and the stereoscopic effects, in avoiding the defects I have alluded to. However, as I am far from considering the case to be quite desperate, I intend to resume my researches as soon as I have leisure to do so. What gives me some hopes of success is the attempt I made years ago. The result has been incomplete and imperfect, but if I have not succeeded in obtaining at once the motion and relief, I have gone so far as to show figures which appear really to be in motion, and preserving all the correctness and distinctness of the photographs.

My ambition to obtain the stereoscopic effect with the movement of the figures having (I hoped only momentarily) been foiled, and not being satisfied with partial success, I did not like to publish an incomplete attempt, and for this reason, till now, kept it only for the curiosity of a few intimate scientific friends. But years are passing away swiftly, and as I do not feel, at my period of life, that I can reckon upon endless time and inexhaustible activity to complete many labors, I did not like to let another meeting of the British Association pass without availing myself of the opportunity of bringing before this annual scientific congress a very simple contrivance which (if I do not later succeed in solving the whole problem) will, at all events, perhaps, call the attention of others to the subject, and induce them to try their hands and brains at its solution.

This is one of the many instances of the advantages of the British Association. Once a year all the branches of science of the world are brought together to show the progress made, and point out the progress to be made. All the devoted followers of those sciences consider that they are obliged to contribute their mite, however small it may be, to increase the general interest of the meeting, and to awaken the desire for further improvements and new discoveries.

As it will be seen by the instrument I submit to the meeting, it is very easy to obtain the illusion of moving figures, but without stereoscopic effect. In this instrument, my first object having been only to try the principle, I have constructed it in the simplest form capable of showing the motion of the figure, and I have found that only two pictures are sufficient to elicit the phenomenon, although the illusion of

reality suffers from the abruptness of two extreme movements, and from the deficiency of intermediate positions.

But nothing is so easy as to employ eight different pictures in as many different stages of action, and with this number of pictures the effect will be sufficiently complete. For this, having placed in the stereoscope two separate cubic frames, revolving independently on the same horizontal axis, I have only to fix on their four sides at right angles two sets of four pictures, making eight pictures, which are made to pass in consecutive order, one after the other, before the lenses of the instrument, and the figure will appear to assume consecutively eight different stages of the whole action. The instrument in its simple state, with only two pictures, will suffice to illustrate the principle, and, at the same time, to elicit some curious phenomena of the perception of vision.

It is known that the retina has the power of retaining for a short time the impression or the sensation of the image which has struck it. Now, availing myself of this property, I have constructed the instrument in such a manner that, by means of a slide with one hole, I can, by moving it rapidly in a reciprocating horizontal direction, shut one lens while the other remains open; and in continuing that motion, while one eye sees one of the two pictures, the second eye cannot see the other picture.

Now, if, before the sensation of one eye be exhausted, the slide shuts the lens and opens the other, a new impression is produced on the retina, and we have an uninterrupted sensation vision, as if the object had moved before us; and if a sufficient number of pictures represent that object in the various consecutive positions it has assumed during several stages of its motion, we experience on the retina the same sensation we have when we see the object itself while it is moving; and, although the pictures in their limited number do not, and cannot, show all the intermediate positions of all the stages of a continuing action, still the mind has the power of filling up the deficiency, as it does, if, when looking at a real object in motion, we accidentally wink the eyes, or an obstacle happens to pass before us and the object. Although during that short interval we have lost the perception of a certain progress of the action, the mind has, as it were, guessed and represented to itself what ought to have taken place during the winking of the eyes, or during the intervention of the passing obstacle, and by that power of the mind there has been no interruption in the whole perception.

This is exemplified in the most forcible manner when we have only two pictures to look at alternately—one with the right and the other with the left eye, as it is with the instrument I have constructed for my experiment. One of the pictures represents the beginning of an action, and the other the end of the same action. By moving the slide one way the right eye can see the picture representing the figure in one position, and the picture showing the other position is invisible to the left eye. Now, by moving the slide the other way the left eye sees the figure in the second position, and the first position is invisible

to the right eye. Now, although we have only seen the figure in two extreme positions—one showing the beginning of the action and the other its end—still we have had the illusion of having seen the intermediate positions.

This is fully illustrated by the pictures representing two boxers. In one picture the arms and fists of one of the pugilists are near his body, as if he were preparing to hit his opponent; and in the other picture they are extended in the act of striking the blow. We have not seen the intermediate position which the boxer ought to have gradually assumed during the whole fight, but we know that they must have taken place, and our mind completes the action. This mental perception is due to the sensation which we expect from habit and judgment, and we feel it as if it had been truly realized.

Another curious phenomenon is elicited by the alternate vision of the two eyes consecutively. We see the object without any difference or interruption, whether it be by the right or the left eye. The ultimate sensation on the mind is the same from whatever eye it has been carried to the sensorium of vision. Whether the object be seen by the right or by the left eye the sensation is exactly the same, and we cannot even distinguish which is the eye that has had the perception; so that if, while we have both eyes open, an object be passing before us, or if we move the hand before the eyes in such a manner that it hides alternately the vision of one and of the other eye, we do not feel that the vision is passing from one eye to the other, and it is impossible to know by which eye we have had the perception.

This explains the reason why, in the instrument I have constructed—which alternately shows a picture in one position to one eye and a different picture in another position to the other eye—we have a single perception of an object in motion without being conscious that the two actions have been consecutively and separately perceived only by one eye at a time, and in turn by one and then by the other. The result is an uninterrupted perception of an object in motion.

Our sensation of vision is not in the eyes, but only in the single sensorium of vision, to which both eyes convey their separate perception. We have an example of a similar physiological fact in the sense of hearing. Although we receive the sound from two organs in opposite directions, only one perception is felt by the mind; the two sensations, like two drops of water the moment they reach each other, are resolved into one.

If I have encroached too much on the time of the meeting, I have to offer an excuse, which I hope will be kindly accepted. How is it possible to be short when one principle of science irresistably leads us to another? And how can we stop when we begin to unfold the marvellous and innumerable expedients which the Creator has employed to make our senses perfect, and to help our intellect?

Translated for the Journal of the Franklin Institute.

Correction of Ship's Compasses at Sea.

M. Faye suggests to the Academy of Sciences at Paris, a method of determining at any time the error of the compass aboard a ship. This is done by attaching to the ship's log, which is suitably modified as to inclends and form, a compass so arranged that at any moment it may be stopped, and its direction thus registered. The log is towed in the wake of the ship, and at a sufficient distance to be out of reach of its magnetic influence, and when it has taken the true direction of the ship, which, if of proper shape, it will soon do, the compass is registered, hauled aboard, and read. The proposition assumes importance from the perpetual variation of the magnetic constants of iron vessels and sea, and the resulting impossibility of perfect correction of compasses.

In the course of his communication, M. Faye records a curious experiment, which is worthy of repetition and study: Dissolve in an acid, soft iron devoid of any magnetic coercitive force, and then deposit it, by a galvano-plastic process, in a thin film upon a surface of a plate of copper, as is done in coating copper plates with iron, to give them greater endurance. This thin coating of iron, chemically pure, but hard and brittle, will possess so strong a coercitive power that I have heated a plate thus prepared to the melting point of copper without destroying the magnetism which I had before given it.

New Mode of Preparing Formic Acid and the Formic Ethers.

By M. Lorin.

Heat a mixture of oxalic acid with dehydrated or commercial glycerine. At 75° Centigrade (167° Fahrenheit) the reaction begins and is in full activity at 90°, (194 Fahrenheit.) At the same time that carbonic acid is disengaged, a watery liquid passes over containing formic acid. On adding a fresh quantity of oxalic acid, some time after the evolution of carbonic acid has ceased, more liquid passes over and richer in formic acid, and, by successive additions of oxalic acid, the liquid becomes richer and richer in formic acid, until it reaches a limit which is exactly given by crystallized oxalic acid.

The equation $C_4H_2O_8, 4HO = C_2H_2O_4 + 4HO + C_2O_4$, shows that 126 grammes of oxalic acid give 82 grammes of aqueous formic acid, which ought to contain, and does in fact contain, 56 per cent. of absolute formic acid.

This preparation of formic acid is so continuous and regular as to be one of the easiest of chemical operations. It is useless to observe the temperature, for the development of carbonic acid indicates the beginning and the end of the operation.

To prepare formic acid of 75 per cent., I act upon glycerine saturated with dehydrated oxalic acid. But, in this operation, more care must be taken of the temperature, to avoid swelling, as the decomposition of the oxalic acid begins below 50°, (112° Fahrenheit.)

When, to the saturated glycerine, we add at the same time oxalic

acid, and the alcohol corresponding to the ether which we wish to obtain, and in about equivalent proportions, the reaction which I have before stated takes place, and the formic acid in its nascent state combines with the alcohol. It is better to condense the vapors within the retort, and not to distil until some time after complete decomposition of the oxalic acid. The ether is purified in the usual way.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, October 18*th*, 1865.

The meeting was called to order with the Vice President, Professor Fairman Rogers, in the chair. The minutes of the last meeting were read and approved. The minutes of the Board of Managers were reported, including the following points of general interest:

Committee on Instruction have reported to the Board of Managers that the lectures will commence on Tuesday, 31st inst. Professor H. Morton lectures on Tuesday evenings on Mechanics, and Mr. Albert R. Leeds on Thursday evenings on Chemistry, for twenty weeks; and that arrangements are being made for some lectures to be delivered at the Academy of Music during the winter, of which due notice will be given.

The Executors of the estate of A. S. Roberts have notified the Board of Managers that Mr. Roberts has devised to the Institute $1000, to be paid in five yearly installments, to be appropriated to the purchase of books and the improvement of the library.

The following donations to the library were also reported: From the Society of Arts, London; the Board of Public Works, Chicago, Illinois; the Mercantile Library Association, New York; J. B. Lippincott & Co., and Professor John F. Frazer, Philadelphia.

The minutes of the various Standing Committees were then reported.

The Special Committee on Steam Expansion reported that their experiments had reached an advanced state of progress, and that a report embodying their results might be looked for at the next or following meeting.

A paper was then read by Mr. Brown on "The Problem of Aerial Navigation in its Mathematical Relations."

The report of the Secretary on new discoveries and inventions was then read as follows:

Secretary's Report.

Engineering Works.—On account of the great time which must yet be consumed before the Mont Cenis tunnel is finished, four and a half miles yet remaining to be executed, it is proposed to supply the break by a temporary track over the summit of the mountain. An experimental line of one and a fourth miles has been constructed on the most difficult portion of the route, with a view of testing the efficiency of this plan, and, as we see by the report of Captain Tyler, of the Royal

Engineers, sent out by the London Board of Trade to examine this work, this distance of one and a quarter miles is ascended in $8\frac{1}{2}$ minutes with a load of 16 tons, though the average grade is so steep as 1 in 13, and at a maximum of 1 in 12. The plan adopted to obtain adhesion is an arrangement of horizontal drivers biting on a central rail.

This plan is much commended in the foreign journals, and is described as new, although to the best of my knowledge it was invented and patented in this country by a member of this Institute very long ago, and was used on some road in this State with satisfactory results. Some of the older members present can probably confirm and give precision to this general statement.

Mr. Coleman Sellers.—The use of the two outside rails and one central adhesion rail, was patented many years ago by Mr. George Escol Sellers. The person to whom Prof. Morton alluded was Mr. Trautwine, the engineer of the Panama Railroad, who advocated the use of this plan across the Isthmus. The engines were so built, but the engineer who succeeded him concluded to cut down the road and use common engines. Since that, there was a road proposed in Pennsylvania, and two engines were built for the road in Cincinnati. An engine was run in New York on this plan, weighing 1100 pounds, which was capable of drawing 30 persons up a grade of 250 feet to the mile with ease. The plan on which they are constructed was better than that at present used in Europe, as they were so constructed that the whole weight of the train should act in producing adhesion, so that, the heavier the load, the harder the grip on the centre rail. We have at present in use at our own works a hammer operating upon the same plan, so that, the heavier the hammer used, the greater will be the bite of the wheels which lift it. I speak of this invention because I think it is due to America to say that it is purely American, and was advocated and used so long ago that the patent has expired; so that you can judge very well that we have precedence of any other country in this case.

Mechanics.—Under this head we would first call your attention to a new form of gas regulator, invented by Dr. Charles M. Cresson, of this city, claiming great delicacy of adjustment, and capacity to pass a large amount of gas, also compensating for the friction of service pipes by increasing the pressure automatically in proportion to the amount of gas passing through.

This regulator consists of a tank with the inlet and outlet pipes, I and O, passing up through the bottom to above the water level W. Within the tank is floated the gas holder H.

The adjusting valve V, secured to the gas holder by a loose link, is formed from a cylindrical plug (fitted loosely to a long cylindrical seat) having pyramidal excavations in its surface with their apices downwards towards the base of the valve. These excavations run out at different points, usually three in number; one extends entirely to the base. The next is two-thirds the length of the valve, and the third is one-third the length of the valve.

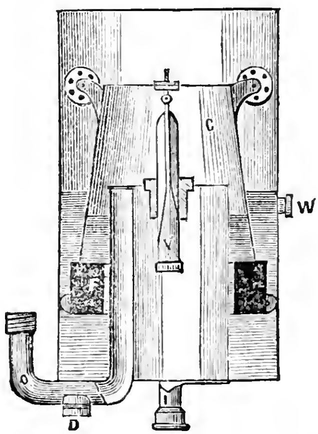
When the valve is but little open, the gas has passage only through

the triangular gutter found by the first excavation, and as the valve sinks to give a greater supply, this gutter gradually increases its sectional area until it is assisted by the second, and finally the third excavation.

In this manner a small amount of gas is passed through a channel of small dimensions and great length; but when a large amount is required, the valve presents the area of the three excavations, and at their largest section.

With ordinary pressures the valve has one inch of motion for use with one burner, whilst the two remaining inches will furnish a supply for twenty burners.

The gas holder H is a frustrum of a cone, the result of which form is to present to the lifting pressure of the gas a constantly diminishing area as it sinks into the fluid to open the valve, and consequently gives an increasing pressure whilst increasing the supply of gas. The amount of coning has been adjusted by experiment so as to increase the outlet pressure sufficiently to compensate for the loss of pressure in the fittings by the addition of many lights.



The fluid preferred for use in the tank is crude glyceringe, as it does not freeze easily nor evaporate, and has no corrosive influence upon the metal of the instrument.

The experimental trials made with the instruments were as follows:

For delicacy of adjustment. Gas was passed through the regulator to a branch upon which were burning twenty-one lights. All of these with the exception of one (a union jet at its maximum) were suddenly extinguished by a master cock, the single burner remaining without change, the pressure gauge showing a vibration of less than one-twentieth of an inch.

The pressure upon the inlet of the regulator was then increased successively to two and three inches without change upon the gauge upon the outlet of the regulator, as was also the case when one burner or all were lighted.

To show the result of checking off at the meter stopcock, as is frequently done where no regulator is used, the branch with the burners was connected directly to the street main without the intervention of the regulator, ten of the burners lighted, and the pressure adjusted by a stopcock to eight-tenths of an inch. When all but one were extinguished, the pressure rose to thirteen-tenths, the burner blowing. When twenty burners were lighted, the pressure fell to three-tenths of an inch.

An experimental trial was then made as to the quantity of gas consumed by the burners when under regulation to their maximum econ-

omy, and also the amount consumed by the same burners when subjected to the ordinary variations of street pressure, as observed during the present evening.

The result showed that with the regulator there was uniformly 78 cubic feet of gas per hour consumed by twenty-one burners, or 3·7 cubic feet per hour per burner. Whilst without the regulator the same burners consumed from 106 to 140 cubic feet per hour, the average being 126 cubic feet, or 6 feet per hour to each burner, the amount of light being not nearly proportionate to the increased cost. The burners being in the first instance properly adjusted to the wants of the consumer, all increase of light would be waste and loss.

Again we would call your attention to a plan for sharpening the teeth of saws, by grinding on a wheel of emery and vulcanite or hard rubber, the invention of Joseph F. Tuder, of this city. The effect of grinding on a wheel is, of course, to give a hollow face to the teeth, which causes them to cut better and for a longer time than when they are made flat or even rounded, as must be the case in filing.

The famous instrument maker of Paris, Deleuil, has brought before the French Academy an air pump in which all lubrication and packing are dispensed with. The piston is made very long, (twice its diameter,) is fitted very accurately to the cylinder, and has a number of horizontal grooves cut around its surface.

It is then found to be air-tight by reason of the capillary attraction of the air in the narrow space included between the cylinder and piston. With a small receiver on the pump plate, a vacuum of four millimetres of mercury can be obtained by this apparatus.

In the *Practical Mechanics' Journal* for September, we find the translation of an article on the mechanical puddler employed at the Closmortier forge, by MM. Dumeny and Lemut. This article is accompanied by many drawings, and is of great interest as showing the exact means employed in this important modification of iron working, and many of the results obtained by the new method.

A report has been made by the Société Industrielle de Mulhouse, on the Lenoir gas engine, the main conclusions of which may be thus briefly stated:

1st. That this motor consumes per horse power per hour 105 cubic feet, while a steam engine of like effect would consume 11 lbs. of coal in the same time.

2d. The gas engine requires an immense amount of oil, as much, in fact, as $2\frac{1}{2}$ pints per horse power per day.

3d. The gas engine, again, requires constant and close attention on the part of the person running it, rendering it impossible for him to do any other work at the same time.

4th. The cost and care of the battery working the induction coil, which ignites the gas, is an item not included in steam motors.

All these are drawbacks to the machine in question. On the other hand, it presents the following advantages:

1st. It consumes fuel only while actually running. Thus, when

required for intermittent work, it may compare well even in economy with a steam engine, whose fire must be constantly burning.

2d. Its perfect freedom from danger.

3d. Its convenience of form, admitting of its introduction into any building, as it requires no furnace, fire, or the like.

Lastly, under this head of mechanics, we would bring to your notice this little apparatus called an atomizer, for scattering perfumed or medicated liquids in impalpable spray through the air of an apartment. It consists (as you see) of two glass tubes placed at right angles to each other, and kept in position by a little bracket of brass. We dip the longer of these in a vessel containing the liquid to be scattered, and then blowing through the other across the upper end of the first, produce a rarefaction in this, which causes the liquid to rise in it so as to be scattered in a fine mist from the upper end by the powerful blast of air. This instrument is invented by S. Maw, of London.

Optics.—Under this head we would introduce to your notice a plan for constructing cheaply large parabolic mirrors, of an enduring and light material, invented by Mr. J. Marshall.

In this case the frame or mould is formed of thick paper, moulded or otherwise worked into the required shape. To the inside of this are attached scales of mica, plated with metallic silver. The result is a reflector, light, durable, easily repaired, powerful in its reflecting action, and cheap in its first cost. Several of these mirrors, of various dimensions, were then exhibited, and their efficiency practically demonstrated. One of them, intended for lighting a skating pond, was four and a half feet in diameter.

Attention was here directed to a plan by which chemical and other reactions could be exhibited to a large audience, by the employment of a magic lantern, but the experimental demonstration of these was deferred until after the adjournment of the meeting.

Chemistry.—We have to notice two important plans for the preparation of the common alkalies directly from mineral substances found in great quantities and easily obtained.

Potash from feldspar. Feldspar, fluorspar, and chalk are pulverized, mixed, and calcined. Fluoride of silicon is disengaged, silicate of lime is formed, and the potash set free,—may be dissolved out by boiling water,—and freed from any lime present by carbonic acid. Some feldspars are, however, found to contain large quantities of soda, and yield on treatment that base.

Soda from cryolite. Cryolite and lime are pulverized and calcined, insoluble fluoride of calcium is formed, and a soluble compound of alumina and soda. This is dissolved out with water, which is then treated with carbonic acid, by which carbonate of soda is formed, and the alumina is precipitated. The Pennsylvania Salt and Alkali Manufacturing Company sent out last winter their chemical superintendent, Mr. Henry Pemberton, together with Mr. S. Lewis, to Copenhagen, where these gentlemen arrived about the 1st of December. They there made arrangements with the owners of the cryolite mines in Greenland,

Messrs. Shure & Sons, and with the Danish government, for the right of mining that material. Ships were then chartered in England, in Quebec, and in our own ports, to proceed to Ivigtus, Greenland, lat. 59°, load with the mineral, and bring it to this port. Six thousand tons have thus been imported up to this time, and a portion of the material is already undergoing treatment at the works of the company near Pittsburgh.

At the request of the members present, Mr. William Sellers then stated some of his observations during a late visit to England, as follows:

Whilst in England, I noticed great progress in all the industrial interests, the most remarkable being in the manufacture of steel. Formerly this business was confined to the manufacture of steel for cutlery purposes and other small objects, the use of it in large masses being unknown; but within the last six years, the general introduction of the Bessemer process, as well as that employed at Mr. Krupp's works in Germany, have revolutionized the trade, so that work which, under the old system, would require an immense number of hands, can now all be done upon the Bessemer plan by a few, making the steel thus produced comparatively cheap, so that it can be applied to ordinary purposes where iron has heretofore been used. It is probably true that this process will not produce the best quality of steel, but the material obtained is, at least, far better than any other equally cheap. By the Bessemer process, up to the point of converting into steel, labor is almost dispensed with, the operation of puddling being entirely abolished. The various movements required are all performed by hydraulic machinery controlled by one man, and it is interesting to see with what facility large masses of molten metal are handled, ten tons often being taken off at a heat. The pig metal is melted in an ordinary reverberatory furnace, and the speigleisen in another smaller one from which they are run into the converting vessel. This is a large egg-shaped vessel open at the top, and suspended upon trunions, so that it may be tipped upon an angle in order to bring its upper or open end under the spout, from which it receives its molten charge of iron. The bottom of this vessel is double, so as to form an air chamber, communicating through the trunions with the blowing cylinders, which produce the blast. The tuyeres are between the air chamber and the inside of the converting vessel, and when this is tipped on one side to receive its charge, the tuyeres will be above the molten iron. The blast is then applied, the converter tipped back to a perpendicular position, and the air rushes through the molten mass, burning out its carbon. When this is accomplished, the converter is turned on its side, the blast shut off, and the mouth passed under another spout to receive its charge of speigleisen. This produces a violent ebullition, and when this has subsided the conversion into steel has been completed.

The converter is now once more tipped upon one side, and the steel is poured into the ingot moulds, which are arranged in a semicircle about the centre of the hydraulic crane which carries the

converting vessel, the whole process being completed in almost as little time as it requires to describe it. After the ingots are sufficiently cool, they are removed to the heating furnaces, and from this point to the hammer or rolls, the subsequent processes are the same as in the manufacture of iron, although requiring machinery of more massive character, owing to the greater density of the material to be operated upon. In the process followed at Krupp's, and other similar works, the metal is melted in small pots, and then poured into one large enough to contain the quantity required for the intended casting, and from this it is let into the mould by withdrawing a plug in the bottom. I have seen gear wheels of excellent finish cast in this way, and large quantities of railway wheels and tires are thus made, the field for its use continually widening. The character of the steel made upon this process is as yet much superior to that made upon the Bessemer principle, and, it will be observed, there is one radical difference, the one rigidly excluding the air from the molten metal, whilst in the other, it is intimately mixed, but whether this is the cause of the difference in quality must be determined by more extended experience. Those engaged in the manufacture expected to make farther improvements, and from what I learned of their operations I believe that in a few years they will cast as large a piece as a twenty-inch gun of steel.

PROF. ROGERS.—They are making Bessemer steel in Troy, N. Y. Mr. Lamborn, of the Iron and Steel Association, is not here, or he would tell us something about it. Did you observe anything new in machine tools.

WM. SELLERS.—I knew they were preparing to make Bessemer steel there, but was not aware that any was produced as yet. The introduction of steel in masses has necessitated larger and stronger machine tools, but I did not observe any other change; that of size, however, is remarkable. Sir Wm. Armstrong's works, at New Castle, in the Ordnance Department, contain many fine specimens of tools, but they are for special purposes. The tools required for rolling and dressing cast steel tires are also remarkable for their enormous size and strength.

COLEMAN SELLERS.—Is the tire round, or is it necessary to turn it?

WM. SELLERS.—They turn it out on the inside at the works. They have made special machinery for the whole of this work, and nearly all steel tires as yet have been made from pot metal. The process of casting from pots is very interesting. From the great number of pots used, and the necessity of bringing them to the proper heat, and pouring into one reservoir at the same time, it is necessary to have all the men as thoroughly drilled as a regiment.

COLEMAN SELLERS.—You spoke of the movement of these large masses of metal. How is it accomplished ?

WILLIAM SELLERS.—Entirely by hydraulic pressure. All the operations are performed in that way, excepting in the rolling of armor plates; in that case they use a traveling crane over head, and upon that

a steam engine and boiler. From this all the movements are obtained, the whole being under the control of one man.

The Vice President announced that the two turreted iron-clad *Monadnock* would leave the Navy Yard in a few days, for San Francisco, by the Straits of Magellan. She will be part of the squadron under the command of Commodore John Rodgers.

As she will go from north to extreme south magnetic latitude, and through a difference of longitude in which the declination of the needle will vary greatly, the opportunity of making observations connected with the permanent and variable magnetism of the ship and the action of her compasses will be an uncommonly good one.

Professor Harkness, of the Navy, late of the Naval Observatory, will go out in her, expressly for the purpose of making observations, which he may find necessary or possible.

The vessel will probably be swung at thirteen or more ports on the way, and careful shore observations will be made at the same points.

Altogether results may be expected which will materially extend our knowledge of the magnetic behavior of these new iron vessels.

The Vice President also mentioned that he had been experimenting lately with asphalte as a flooring for stables. The artificial asphalte, made from coal tar, such as is used in gravel roofs, was used, mixed with clean gravel in the ordinary manner, and laid on the hard clay to a thickness of two and a half inches, finer gravel being used at the top than at the bottom. The top was finished with a coat of hot, fine gravel, pressed into the asphalte, and the loose gravel swept off.

The use of the *artificial* asphalte for a floor for horses to stand upon, is believed to be new, and the result of the experiment as to wear will be reported after it has been tested.

The meeting was then, on motion, adjourned.

HENRY MORTON, *Secretary.*

BIBLIOGRAPHICAL NOTICE.

Curious Facts in the History of Insects. By FRANK COWAN. Philadelphia, Lippincott & Co., 1865. 12 mo. pp. 396.

An excellent little book, making no pretensions to technical science, but showing great industry and research on the part of the author, excellent taste in the selection of his materials, and good literary powers in presenting them. We found it very readable and amusing, and it is excellently presented to the public by the publishers. We hope this will not be the last we are to hear from the author.

A Comparison of some of the Meteorological Phenomena of SEPTEMBER, 1865, *with those of* SEPTEMBER, 1864, *and of the same month for* FIFTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 11¼′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

	September, 1865.	September, 1864.	September, for 15 years.
Thermometer—Highest—degree, .	89·00°	81·00°	95·00°
" " date, .	4th & 6th.	24th.	12th, '51.
" Warmest day—mean,	82·50	75·00	85·20
" " " date,	12th.	24th.	6th, '54.
" Lowest—degree, .	49·00	51·00	39·00
" " date, .	19th.	26th.	25th, '56.
" Coldest day—mean,	56·83	58·50	51·30
" " " date, .	19th.	25th.	30th, '53.
" Mean daily oscillation,	11·90	12·30	16·16
" " " range, .	4 81	4·82	4·68
" Means at 7 A. M., .	70·73	63·22	63·15
" " 2 P. M., .	77·85	70·78	74·61
" " 9 P. M., .	73·42	66·32	67·00
" " for the month,	74 00	66·77	68·25
Barometer—Highest—inches, .	30·225 ins.	30·117 ins.	30·430 ins.
" " date, . .	28th.	8th.	16th, '51.
" Greatest mean daily press.	30·169	30·072	30·381
" " date, . .	27th.	7th.	16th, '51.
" Lowest—inches, . .	29·583	29·450	29·281
" " date, . .	6th.	24th.	18th, '63.
" Least mean daily press.,	29·672	29·533	29·403
" " date, . .	6th.	24th.	16th, '58.
" Mean daily range, .	0·109	0·103	0·121
" Means at 7 A. M., .	29·950	29·786	29·957
" " 2 P. M., .	29·888	29·760	29·915
" " 9 P. M., .	29·933	29·795	29·939
" " for the month, .	29·924	29·780	29·937
Force of Vapor—Greatest—inches,	0·874 in.	0·741 in.	0·991 in.
" " " date, .	14th.	24th.	6th, '54.
" " Least—inches, .	·256	258	·161
" " " date, .	19th.	25th.	29th, '60.
" " Means at 7 A. M., .	·604	·442	·477
" " " 2 P. M., .	·621	·439	·497
" " " 9 P. M., .	·631	·454	·516
" " " for the month,	·618	·445	·497
Relative Humidity—Greatest—per ct.,	93·0 per ct.	97·0 per ct.	100·0 per ct.
" " " date,	18th.	5th.	2d, '54.
" " Least—per ct.,	36·0	39·0	29·0
" " " date, .	16th.	16th.	2d, '59.
" " Means at 7 A. M.,	77·4	74·5	78·1
" " " 2 P. M.,	63·5	57·8	56·4
" " " 9 P. M.,	74·6	69·5	74·0
" " " for the month	71·8	67·3	69·5
Clouds—Number of clear days,* .	8	8	11·0
" " cloudy days, .	22	22	19·0
" Means of sky cov'd at 7 A. M.,	73·0 per ct.	62·3 per ct.	57·1 per ct.
" " " " 2 P. M.,	55·3	70·7	52·5
" " " " 9 P. M.,	32·7	47·7	36·0
" " " for the month	53·7	60·2	48·5
Rain—Amount	6·576 ins.	7·317 ins.	4·240 ins.
No. of days on which Rain fell,	10·	13·	8·2
Prevailing Winds—Times in 1000,	s.63°26′ w·167	s 69°25′ w ·244	s87° 41′ w ·187

* Sky one-third or less covered at the hours of observation.

JOURNAL

OF

THE FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

DECEMBER, 1865.

CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

On the Condensation of Steam in the Cylinder due to Expansion.

By Fred. J. Slade.

Much has been written of late to prove that the long received opinion, that a great economy is derived from working steam expansively, is quite fallacious; and, notwithstanding the vast amount of practical evidence in favor of the old belief from the well known results of most extensive practice, both in this country and abroad, many have had their faith shaken in the value of more than a very limited amount of expansion, partly by a few experiments perhaps not altogether free from sources of error, and to a greater extent, no doubt, by arguments put forth by persons who should have had great experience, and whose views therefore carried with them considerable *prima facie* weight. In this train of argument the main assumption has been that there is, as a necessary consequence of the act of expansion, a great condensation of steam in the cylinder, and this has been dwelt on in some instances till the most alarming effects would appear to result from it. Starting with a most singular fallacy as to the relative amounts of heat in steam of high and low pressure.* Mr. Isherwood has pictured to us how this condensation mul-

* Mr. Isherwood states, (p. 56, "Engineering Precedents," vol. ii:) "Although the total heat of steam of higher pressure is greater than the total heat of steam of lower pressure, yet, as the latent heat of the latter increases in a much higher ratio than its total heat diminishes, and as this increase in the latent heat is at the expense of the sensible heat, it (expansion) becomes a cooling process and produces the condensation stated." That is, after admitting that the total heat which includes and is the sum of the latent and sensible heat is greater in high than in low pressure steam, he claims that this greater total heat will not be sufficient for the less. He must forget that in lowering the pressure the sensible heat diminishes faster than the latent heat increases, and, *therefore*, it is that the total heat is less in the lower pressure steam. The diminution in the sensible heat yields up, so to speak, more heat than the increase of latent heat demands; hence steam expanded from a higher pressure without doing any work is slightly superheated.

tiplies itself beyond measure. Unfortunately, those who have written upon this subject have discussed it entirely in general terms, instead of bringing it directly to the test of numerical calculation, as it is possible to do, and thereby ascertaining exactly what the amount of condensation is, and what loss of power results therefrom.

The total heat of steam increases slightly with the pressure. If then steam could be expanded without being allowed to do any external work, as, for instance, by allowing it to expand into a vacuum, the steam after expansion would contain slightly more heat than was due to its pressure, or, in other words, would be slightly superheated. This fact has been beautifully illustrated experimentally by Professor Tyndall, using a vessel of compressed air, which, being allowed to expand into a vacuum, it was shown that the amount of heat absorbed in starting the particles of air into motion was exactly balanced by that given out in bringing them to rest again; and no other work being done, no heat was absorbed. This gain of heat in the case of steam is from 20 to 25 per cent. (according to the pressure) of the amount absorbed when the expansion takes place against resistance. In the steam engine, however, the case is different; for here the steam *does* work in expanding and absorbs an equivalent amount of heat, which has to be supplied by the condensation of a portion of the steam. The exact amount of heat required is readily found from an indicator diagram—every 772 lbs. of pressure through one foot of stroke requiring an absorption of an amount of heat competent to raise the temperature of 1 lb. of water 1° F. Now, it has been assumed that the expansion of the steam to fill the vacancy caused by the condensation necessary to supply this amount of heat, was the cause of a further absorption of heat and consequent condensation. That this is fallacious is evident when we reflect that the heat equivalent to the work done in moving the particles of steam is exactly replaced by the act of bringing them to rest again; just as a body moving in a vacuum gives out as much force in being stopped as it originally required to set in motion. Moreover, as the condensation of steam due to the work done reduces slightly the pressure, there is a slight excess of heat which goes to lessen, to a small extent, the condensation.

The force required to remove the particles after the piston, involves a disappearance of heat during the continuance of the stroke, and a consequent diminution of pressure. This heat, though given out again when the particles are brought to rest at the end of the stroke, is lost as far as direct power is concerned, but goes towards heating the piston and cylinder. The absolute amount of heat required in thus moving the particles of steam, is, of course, small, and yet as this loss has been urged as one of the objections to expansion, let us give it its exact value, which is found as follows: When the steam is cut off at half stroke, the work done in the act of expansion itself is the moving of all the steam in the cylinder through a distance equal to one-quarter the stroke, in the time of half the stroke. If cut off at one-third stroke it is the moving of all the steam a distance of one-third the stroke, in the time of two-thirds the stroke. If cut off at one-

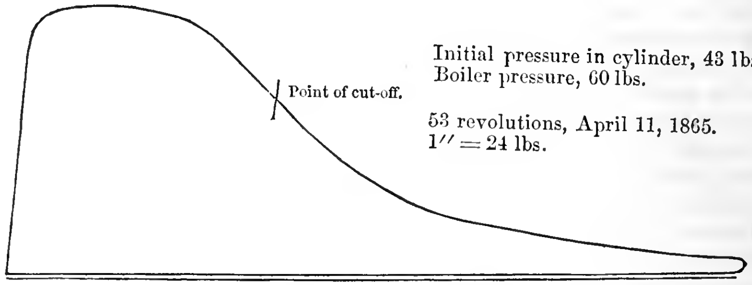
quarter stroke, the steam is moved three-eighths the stroke in the time of three-quarters of one stroke, and so on for other degrees of expansion, each of which would be equal to the whole mass of steam moved a distance of half the stroke in the time of one stroke, were the spaces moved through exactly proportional to the times. The difference due to this inequality being insignificant, and the total amount of work extremely small, we may assume this value as abundantly accurate. Now, suppose the mass of steam to be 1 lb. and the speed of piston 1000 feet per minute, then the work done will be imparting to this mass a velocity of 500 feet per minute, or 8·3 feet per second, which is about equal to the effect of the force of gravity acting on the same mass through one foot; the work done, therefore, is equal to one pound, raised one foot high—a totally insignificant amount in comparison with the whole work done by the engine during the same time, which in the case supposed might easily be 90,000 lbs. raised one foot. "The condensation due to expansion, *per se*," therefore does not amount to much.

When the exhaust valve opens, the particles of steam rush with great velocity into the condenser, and the acquisition of this velocity involves an absorption of heat. Suppose the pressure in the condenser to be one pound per square inch, and that in the cylinder at the commencement of the exhaust, 15 lbs. Then the work done by 1 lb. of steam in expanding through this difference of pressure will be 109,829 ft. lbs. = 142 units of heat. Of this, 37,872 ft. lbs. are employed in overcoming the head resistance in the condenser of one pound per square inch offered to the expansion of the steam. The remaining 71,957 ft. lbs., were the steam unimpeded in its flow, would impart to it a velocity of 2145 ft. per second. Owing to friction, &c., the actual velocity will always be less than this, and the difference between the number of ft. lbs. adequate to produce the actual velocity and that already given (71,957) is the measure of a portion of the work or heat that is returned to the steam and to the sides of the cylinder and pipes in the destruction of motion by friction.

Supposing the pressure at the end of the stroke to be equal to that of the atmosphere, the steam will have a total heat of 1178·6°, and if the temperature of the condenser be 104° F., corresponding to a total heat of steam of 1146·2°, the surplus of heat in the steam remaining in the cylinder during the exhaust stroke would be 32·4°, did it require no heat to set the particles in motion; but the quantity of heat required for this purpose being, as we have found, about 140°, the steam instead of being superheated is partially condensed and deposits moisture on the cylinder.

Now, let us take an actual example and apply the foregoing method of calculation to determine precisely what loss results from the various operations gone through during the stroke. The accompanying diagram is one of a number taken from a stationary engine, 10″ diameter of cylinder, × 20″ stroke, cutting off at about one-third stroke, by a slide on top of the main valve. The average pressure measured on the diagram is 34·5 lbs. The area of a 10″ piston =

78·5 inches, which, multiplied by 34·5, gives 2708·5 lbs. raised 20 inches as the work done by the steam used in one stroke equal to 4514 lbs. raised one foot. This amount of work is equivalent to $5\frac{7}{8}$ units of heat.



The pressure in the boiler was 60 lbs. above the atmosphere, and the initial pressure in the cylinder, 43 lbs. Assuming the gain of heat due to this expansion to have been neutralized by radiation from the steam pipe and chest, we have next to consider the gain of heat from a reduction of pressure from 43 lbs. to 4 lbs. above the atmosphere, which is (1202·5°—1182·7°=) 19·8°. The capacity of the cylinder is ·9086 cubic foot, and the weight of a cubic foot of steam at the pressure of 4 lbs. is ·044 lb. The contents of the cylinder, therefore, weighs ·04 lb., and the increase of 19·8° in this quantity of steam is equal to ·8 of a unit of heat which, deducted from the $5\frac{7}{8}$ units of heat required to do the work, leaves still about 5 units to be supplied by the condensation of the steam. The latent heat of steam of 34·5 lbs. pressure is 934°, and therefore to obtain 5 units of heat, it will be necessary to condense ·0055 lb. of steam or about $\frac{1}{8}$ of the total quantity contained in the cylinder. The gain of heat due to the reduction of pressure arising from this condensation will act to diminish the condensation by about $\frac{1}{60}$ of itself—a quantity too small to be considered in view of the inherent uncertainties of the case, making it impossible to tell from a diagram *exactly* how much steam has been admitted to the cylinder. The pressure at the end of the stroke is 4 lbs. above the atmosphere, or 19 lbs. total pressure. After the opening of the exhaust valve, it falls to 16 lbs. equal to an enlargement of its volume from ·9086 cubic feet, to 1·08 cubic feet. The work done in this expansion is 406 ft. lbs. To raise a column of atmospheric air of an area of 144 square inches, ·171 feet, or, in other words, to overcome a resistance of 2160 lbs. through that distance = 369 ft. lbs. of *external work*. The remaining 37 ft. lbs., minus that absorbed in friction, is the *internal work* of imparting to ·171 cubic feet of steam of 16 lbs. pressure the velocity with which it was ejected by expansion from the cylinder. This velocity we may take as about 400 feet per second, to acquire which a body would have to fall through 2496 feet. The weight of ·171 cubic feet of steam of 16 lbs. pressure being ·0065 lbs. the work done is equal to 16·5 ft. lbs. The sum, therefore, of external and internal work done in exhausting is 385·5 ft. lbs., equal to

one-half a unit of heat, to supply which will require the condensation of ·00052 lb. of steam.

We have thus considered the action of the steam through every portion of the stroke and have found by definite calculation the loss or gain of heat in each operation. We have seen that the principal and only considerable loss of heat is that necessarily abstracted in the act of performing the work—this, of course, is constant for the same amount of work, whether we use the steam expansively or follow full stroke. The work required to drive the particles of steam after the piston in expanding has been shown to be absolutely insignificant, but even if it were of any account, it would operate against the full stroke engine, as in this case a larger mass of steam has to be set in motion. On the other hand, we find that there is a slight gain of heat due to expansion, *per se*, equal in the case we examined to one-seventh the amount required to do the whole work. If this investigation may do anything towards freeing this subject from vague speculations and substituting sounder modes of reasoning, it will not have been undertaken in vain.

Experience, if it be intelligently comprehended, is the safest guide in all such matters; but it helps us in interpreting experience, and suggests new directions for experiment to apply the known laws of physic to obtain a theoretical solution of the problem.

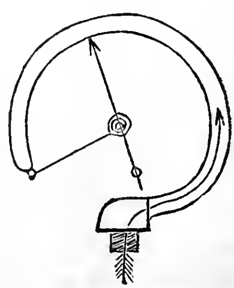
Dry Dock Iron Works, New York.

For the Journal of the Franklin Institute.

The Bourdon Pressure Gauge. By John D. Van Buren.

The essential parts of this gauge are an elastic steel tube bent in the form of an arc of a circle, fixed at one end, and having an elliptical cross section, with its major or longer axis perpendicular to the plane of the circle, together with an index hand connected with the free end of the tube. The elastic medium of which the tension is to be measured is allowed to flow into the tube, and the pressure which it exerts upon its interior surface has a tendency to straighten the tube. The tube, having its external surface exposed to the atmospheric pressure, is generally so adjusted that its readings commence from that pressure as *zero*, *i. e.*, when the internal is equal to the external pressure, the gauge reads 0. If the internal pressure then be diminished below the atmospheric, the tube, in place of straightening, will *coil;* thus forming a *vacuum* gauge, or gauge for pressures less than fifteen pounds per square inch. The *steam* gauge reads the degree of pressure *above the atmospheric pressure at the time.* Fig. 1. It is proposed to explain the action of this gauge.

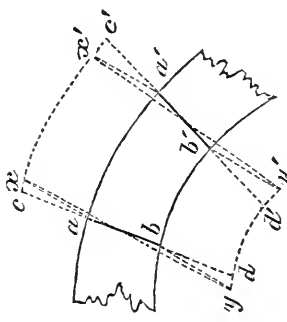
Fig. 1.



Action of the Gauge.—The elastic medium, such as steam entering the tube, will tend to occupy the greatest possible volume. It will, therefore, tend to so

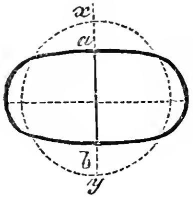
alter the shape of the containing vessel that, with its given bounding surface, it shall have the greatest possible capacity. This is the principle upon which the gauge is constructed. This change of shape causes the tendency to straighten in the tube. Let Fig. 2 represent a meridional section of the tube, *i.e.*, a section by a plane passing through the minor axes of the elliptical sections. Suppose $a\ b$ and $a_1\ b_1$ to be the minor axes of two consecutive sections, represented also in Fig. 3 by $a\ b$. From what has been stated above, it is evident that, upon the admission of the steam or other elastic medium, these sections will have a tendency to assume the form of a circle, since with a given perimeter this figure gives the greatest area, and thus, with the given surface, to give the maximum capacity to the tube. But, in order that these sections may assume the form of a circle, the minor axes $a\ b$ and $a_1\ b_1$, Figs. 2 and 3, must extend. If these sections were perfectly free and independent of each other, this extension would take place in the *radial* lines $a\ b$ and $a_1\ b_1$. The sections are, however, bound together by the material of the tube, which opposes a resistance to the free motion of the points $a\ b$, $a_1\ b_1$. In order to allow the point a to move to c, and the point a_1 to c_1, the filament of metal $a\ a^1$ must be *extended* into $c\ c_1$; and to allow the point b to move to d, and the point b_1 to d_1, the filament of metal $b\ b_1$ must be *compressed* into $d\ d_1$. But the resistances of the material to extension and compression will oppose this action, and therefore the points $a\ b$, a_1 b_1, will take intermediate paths and arrive respectively at the points $x\ y$, $x_1 y_1$, the tendency being to preserve the lengths of the filaments of metal $a\ a_1$ and $b\ b_1$, making $x\ x_1 = a\ a_1$, and $y\ y_1 = b\ b_1$. The *exact* directions could be found by constructing parallelograms upon lines representing the respective radial and circumferential forces and taking the diagonals for the paths of the points $a\ b$, $a_1\ b_1$, during the extension.

Fig. 2.



Now, joining the points $x\ y$, $x_1\ y_1$, by straight lines, it is plain that the consecutive axes $a\ b$ and $a_1\ b_1$, *after extension*, will be represented by the lines $x\ y$ and $x_1\ y_1$, *less inclined than before to each other;* hence, the tube must have *straightened* or uncoiled to a corresponding extent, since the same may be proved for any other meridional section, taking chords in place of the minor axes. In the case of the vacuum gauge, the pressure being diminished within, below the atmospheric pressure, the section will become more flattened, and the tube will *coil up* a corresponding amount; for the filament $a\ a_1$ will be

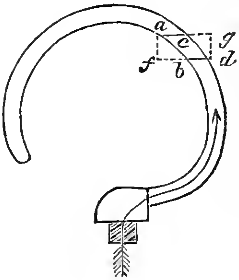
Fig. 3.



acted on by a compressive strain, and the filament $b\,b_1$ by a tensive strain, the reverse of the above.

NOTE.—The writer has frequently heard the following given as an explanation of the action of this gauge: The steam pressure pressing *from* has a greater area to act upon than the steam pressure pressing *towards* the centre of curvature of the tube, by reason of the outer circumference being greater than the inner circumference of the bend of the tube; and hence the tendency to straighten in the tube under an increased pressure. If this were true, then perpetual motion were indeed a fact; for, forming a car in the shape of the crescent moon, and filling it with compressed air, we could fly even to its heavenly prototype, with the rapidly increasing velocity due to an unceasing constant force, unchecked by the ugly fact that reaction and action are equal and opposite,—unincumbered by coal or engine,—could make motors (prime) of our boots by tugging at the straps. This explanation does not at all notice the change of shape of the elliptical sections. Now, consider the elementary areas $a\,b$ and $c\,d$, included between the parallel lines $a\,c$ and $b\,d$, Fig. 4, and suppose no change to take place in the shape of the section. It is evident that the forces tending to push the areas $a\,b$ and $c\,d$ in the directions of the parallel lines are equal and opposite, being measured by the *equal* projections $a\,f$ and $d\,g$ of the surfaces $a\,b$ and $c\,d$ upon a plane perpendicular to these lines. The same may be proved for any other two sections, and for any direction; and hence no motion can ensue *unless the forces of tension and compression are brought into play by a change of shape in the section of the tube.*

Fig. 4.



On Marine Engines from 1851 *to the Present Time.*
By N. P. BURGH, Esq., Engineer.

From the Journal of the Society of Arts, No. 643.

(Continued from page 312.)

DISCUSSION.—Mr. J. CLARKE said allusion had been made to surface condensers, which, he presumed, would render unnecessary the use of salt water in the boiler, inasmuch as the boilers could be charged with fresh water before leaving the port, and this was used over and over again. He was recently in the workshop of a member of the Society, who was largely engaged in the manufacture of salinometers, having then a large order to execute for the government; but, in the event of the universal adoption of surface condensers, he presumed that instrument would be superseded.

Captain JASPER SELWYN, R.N., said, as a naval officer interested in the progress of mechanical invention, he thanked Mr. Burgh for the information he had afforded in his interesting paper. He would remark, in the first place, that only very slight mention had been made of boilers; but a man who took the interest, as Mr. Burgh evidently did, in mechanical questions, would never ignore the source of the power, or deem it unworthy of a place in his paper; for it was clear, so long as we went on with ineffective arrangements to produce the

power itself, it mattered little how much economy was introduced into the arrangements for utilizing the power. The steam boilers of the present day he considered to be a reproach upon the marine engineers of this country. They were very far from producing, at any time, any thing like the results in practice which they produced when sent on trial trips. That was partly caused by the insufficient means of securing the circulation of the water in the boiler, and partly by the bad arrangement of the fuel for firing, by the choking of the tubes with smoke, and by the galvanic action which was speedily set up and resulted in the deposit of large quantities of material all over the heating surfaces. In many ways the boilers required, but had not yet received, the same amount of attention that had been given to the engines. He thought improved means for securing the circulation of the hot water, and of preventing escape, of utilizing fuel, and obtaining complete combustion, were of more importance than any improvement in the engines. He had heard of the introduction of steel with great pleasure, knowing how advantageous it would be in many respects; but if those who employed steel did not consider the electrical action which would result when that metal was brought into contact with copper, a deposit would be produced in the boiler which would go far to neutralize the other advantages. He was very pleased to hear incidentally introduced into the paper a subject in which he had for some years taken an interest, viz: that of twin screws. He was, however, at a loss to conceive on what ground it was said that the twin-screw principle could only succeed in vessels of a certain size, and was not applicable to larger ships. No later than the previous day, the newspapers gave an account of the trial of a vessel of 970 tons, fitted with twin screws, and the results, he had been informed by persons who were present, were correctly reported. Now, that vessel represented what would formerly have been called a large ship, and the question to be decided was to what tonnage were the good effects of twin screws to be limited? In the first instance, it was said that the principle was a good one for boats, and last year Mr. Rennie stated it had been tried with excellent effects in small river steamers, but he doubted the success of its application to any thing beyond that. Subsequently to that, however, blockade runners fitted with twin screws made their appearance, and were completely successful, and since then the experiment had been tried on a still larger scale by ship-builders on the Thames. He deprecated such a decision being arrived at on this point as would prevent us from building vessels for our navy of such steering power as Mr. Burgh had recognized in the twin screws; besides this advantage, he (Capt. Selwyn) maintained there was also an increase of speed. They had a certain draft of water in a screw ship to which they were limited; they might put into the ship engine power as much as they pleased, but they could only utilize the area of water which came against the propeller. If they could increase that area they got more duty done by the engines without "churning" the water, and that was the whole theory of the success of twin screws in giving speed. That principle was perfectly applicable to a ship of war; and the vessel to which he had previously

referred had another valuable quality: she gave, with a draft of nine feet six inches, a speed of $16\frac{3}{4}$ knots with both screws working, and of 12 knots with one screw only working. This showed that even in that vessel the power of propulsion was not utilized to its full extent; the increased velocity did not correspond to the increased horse power used. With regard to the observations in the paper, as to the reluctance of men to copy, he confessed he thought that class of intellect was more rare which knew how to judge properly what to copy, than that which invented for itself a new mode not always better than that which preceded it. The great masters in painting had numberless followers, who called themselves the scholars of those men; and it was no less a credit to these to have chosen well their master than to have produced something original. With regard to the comparison of fuel consumption, it must be recollected, when they got indicated h.p. in proportion to nominal h.p., as 4 or 5 to 1, and the coal burnt was now $2\frac{3}{4}$ lbs., instead of 8 or 9 lbs. per h.p., there was not so very great an advance as might be inferred from the way in which the case had been put. Much more might be done in the way of economizing fuel, by due consideration of the best way of placing the heating power advantageously in the boiler. It was clear, so long as they did not provide for the free descent of the hot water when it had given off its steam, and had become to a certain extent cool—the free descent from the top to the bottom to be re-heated—so long they lost the good effect of the boiler. The injurious effects of scale in boilers had been obviated to a certain extent by the employment of scale catchers or surface apparatus for laying hold of the scale as it floated up, but he thought the better way was to consider any system which formed less scale in the boiler, and with that view fresh water, when once in the ship, might be maintained in the boiler without trouble. They could produce sufficient fresh water for the purpose by the utilization of a small quantity of fuel, so as to supply whatever waste of water took place from condensation. With regard to the general arrangement of engines in ships, he quite entered into the graphic illustration in the paper of a man hung by his heels to inspect the foot valves. He thought engines were made too much like watches. Engineers prided themselves on the small space within which they could place their engines, and by that means subjected the persons who worked them to a great deal of unnecessary inconvenience.

Mr. Rochusson, as one practically connected with the manufacture of machinery, would express his dissent from the statement of the last speaker, that the contact of steel and copper in a boiler would generate a stronger galvanic current than that of iron and copper. [Captain Selwyn said he had made no such statement.] There was no doubt that steel was a very important element in all engines, and he regretted that subject had not been more dilated on in the paper; at the same time, it was well to give a caution as to the indiscriminate adoption of steel for boilers. Steel would bear a higher tension than the best Yorkshire iron, but certain qualities of steel were unfit for boilers from their liability to injury from blistering. The most suitable form of steel for

boilers was cast steel, which could be made of a strength equal to a pressure of sixty tons to the square inch. One great object sought in engines was the avoidance of heated bearings; and the more they reduced the surface of the bearings, and the more they employed metal capable of a highly polished surface, the less were they liable to this evil. The use of cast steel for shafting, was, therefore, a great advantage. It had been found by experience that a cast steel shaft of 9 inches diameter, was equal in strength to one 11 inches in wrought iron. In that proportion, therefore, they saved material in the weakest part of the ship, and they had a stronger construction with less strain upon the engine. They might go from that to cast steel propellers. There was scarcely a greater annoyance on a voyage than the breaking of a propeller. In one short voyage in one of his vessels no fewer than five cast iron propellers were broken. They were not, perhaps, at that time quite up to making good cast steel propellers, but he believed they were so now. The first cost would be greater, but that was more than compensated by the safety and durability which were insured.

Captain Symonds, R.N., reverting to the subject of the twin screw, said that Mr. Burgh, while giving credit to that system for a certain number of advantages, had omitted two or three of the most important. During the last five or six years he had seen something of the practice of the larger class of the twin screw vessels, and it struck him that one of the principle advantages of the twin system was that, in the event of one engine or one screw becoming injured, they had the use of the other engine and screw, by which two-thirds of the power could be obtained in case of emergency. This was exemplified in the trial of the vessel alluded to by Captain Selwyn, when one of the engines being stopped, owing to heated bearings, she was propelled at twelve knots with the other engine; her full speed being rather over sixteen knots. That was a very important thing, especially in a merchant ship, as had been proved in a voyage to America. A twin screw ship had been able to proceed with fair speed and slight consumption of fuel with one engine, while the other engine was being repaired, so that when she arrived out, her engines and boilers were in a good condition to run the blockade without any occasion for delay. If that ship had had only one pair of engines applied to a single screw, it would not have been so capable of performing this service. With respect to the limit of size of ship to which the twin system was applicable, his gallant friend Captain Selwyn's remarks on the subject rendered it unnecessary for him to go over the same ground again, but he would add that it was of the utmost importance to have the twin system adopted in heavy ships in order to divide the power between two engines, which ordinary engineers would then find no difficulty in manufacturing; besides, it was found difficult on board ship to lift out the heavy parts of very large engines for repair. He submitted, also, that the moving parts of these large engines in heavy ships were not so convenient as lighter machinery would be. Another great point was the difference in the amount of friction between the heavy single screw

engines and the lighter engines on the twin system. In addition to these advantages, there was that which was derived from the position of the twin screws, away from the centre of the ship, which not only gave them a great advantage in propulsion, but also placed them away from the extreme end of the dead-wood, where, from the longer leverage, greater vibration would necessarily be produced. In fact, the single screw produced an amount of vibration which was avoided in the twin-screw system. Experience had shown that the twin principle had been applied with the best results to vessels of various sizes up to 500 tons, and within his own knowledge one of these vessels had been doing regular work in towing for the last six years. With a draft of only 3 feet 3 inches, and engines of 30 horse power, she had been continually towing four Dutch barges, with loads of 50 tons each, at 6 knots an hour, which was a result, he believed, seldom obtained by paddle-wheel tugs of the same power and draught of water. The engines were in as good a state as when they were first built, and they had never been known to hang on the centre, which was one of the objections to the single screw engine. He had found the twin system effective for two main reasons. In the first place, the arrangement of the inverted cylinder engines on the A-frame occupied no more room in the ship than a pair of ordinary screw engines, with this further advantage, that it did away with even the slight vibration which was found in vessels of the same character with the engines laid horizontal. He submitted these were points of advantage which ought not to be lost sight of.

Mr. G. F. Wilson, F.R.S., remarked that on the first introduction of surface condensers a difficulty was experienced, which he should be glad to hear had been obviated. It was found that the oil used for lubricating certain parts of the engine, was carried with the water into the boilers, and there, as was well known to chemists, when oil and water were brought together at a high temperature, the oil became separated into its acids and base, the acids being free to act upon the material of the boiler, and upon any impurities contained in the water. This was found to be an important objection to surface condensers. He should be glad to know whether that objection had been removed. In addition to this, the steam was not generated so quickly. It was proposed at one time to use oil not composed of acids and a base, such as mineral oil, which, it had been thought, would not be decomposed by the action of the water, but he had no means of knowing whether this succeeded or not.

Mr. John Grantham remarked that the double-screw system had entered somewhat largely into this discussion. It was a subject of great interest at the present time, and the naval officers who had addressed them had spoken encouragingly of its advantages. There were to this question, as to all others, two sides. The system seemed to be a very captivating one, but he thought its advantages had been somewhat overrated, and they must be cautious not to take up too readily the few examples, which had been presented under perhaps the most favorable circumstances that could be obtained, and to suppose that the system, therefore, had all the merits which those particular vessels

were shown to possess. The builders of those ships understood their business well, and built fast vessels to which they applied the twin screws, and we did not always weigh carefully how the great success had been produced, and whether the same results, or nearly the same, might not have been produced by the single screw. It was, therefore, not unnatural that naval men, who had to do principally with ultimate results, should be very much taken by these experimental vessels, but, he feared, when they had longer experience, some of those advantages would smooth down. As yet there was no proof that two screws would propel a vessel better than one, all other things being equal. He admitted that, if they had a vessel of light draught, and put very high power into it, probably two screws would show a better result than one, from the fact that they gave a larger surface under more favorable circumstances for propelling the vessel and utilizing the power given to her. But he asked the engineers and naval men present to consider all the circumstances of the case. If they wished to have a screw vessel of light draft and great power the double screw might be best, but if they were not limited as to draught of water, and did not require excessive power, the single screw would be best. One disadvantage of the twin-screw system was that it made the interior of the ship more difficult to deal with than when there was only one shaft and one set of machinery. If they could apply all the power favorably to one screw, he thought it desirable to do so. It would not, however, do to dogmatize on this subject, and, whilst he would not advise them to neglect this question altogether, he would caution them against thinking the system possessed all the advantages which had been urged in its favor as having been exhibited in the very fast and well built vessels which had been recently brought before the public.

Mr. W. Hawes confessed his surprise at the observation of one of the naval officers who had spoken, that he considered the boilers on board a great many of our ships were a disgrace to the present state of science. When they found it to be the fact that the quantity of fuel consumed had decreased from an average of 5 lbs. or 6 lbs. to $2\frac{1}{2}$ lbs. per indicated h. p., he thought it showed a great amount of progress. That result might be obtained, not simply by having the best form of boiler and the best mode of applying the fuel, but likewise by the perfection of the machinery which was driven. The measure was the fuel required, not to evaporate a given quantity of water, but to drive an engine of a certain power. That engine would be driven with the less steam, the more perfect was the machinery; therefore, the consumption of fuel was not only a test of the efficiency of the boiler, but also of the machinery which was driven by it. Undoubtedly, he agreed that the economical utilization of fuel was one of the most important elements of progress in marine engines. There were two difficulties staring the engineer in the face: first, how to put the largest amount of available power on board a vessel of a given size; and, secondly, how to stow sufficient coal to make that power effective for a long voyage. In all long voyages, the period during which a vessel could run under steam was so limited, that it was a matter of the greatest importance

to make arrangements by which a supply of fresh fuel could be ensured at frequent stations. For his part, he believed the progress in the construction of boilers had kept pace with the improvements that had been introduced into steam machinery, and that our present boilers, so far from being a reproach to our engineers, were evidence that they had been as successfully occupied in this branch of manufacture as they had in the production of the most perfect machinery the world had ever yet seen. With respect to the twin-screw system, he was inclined to think if that plan had hitherto been the ordinary one for propelling vessels, and the single screw introduced for the first time, we should be struck with the simplicity of the machinery required in the latter instance to produce the same results. In the statement of the work done by the twin-screw ships, there was an omission of the speed obtained by each vessel; but in the table by Messrs. Penn, this information was given. The very feature by which alone we could judge of the real value of the twin system was omitted. The adoption of twin screws, it was to be remarked, involved a double risk of fouling, and if there was one difficulty more than another with regard to screw ships, it was the accidents which happened to the propellers from fouling with substances floating on the water, and certainly two small propellers were more likely to be injured in that way than one large one. Moreover, the hold of a vessel was better adapted for one pair of engines with one shaft and one screw, than for having all those parts duplicated, and consequently, weaker and more liable to derangement. Although there might be advantages in this system for shallow waters and light draft, he believed, where the screw was well immersed, the single propeller was more effective. They could not but feel much indebted to Mr. Burgh for bringing this subject before them; whether connected with war or peace, with the navy or the merchant marine of the country, there was scarcely a question of equal importance to the nation. It was essential that we should have the best ships, the best boilers, and the best engines, to enable us to perform the longest voyages in the shortest time, with the least amount of risk to the lives and cargoes conveyed.

Captain Symonds begged to state that there had been no instance recorded of the fouling of twin screws, and he believed that they were far less liable to foul than the single screw.

The Chairman said, looking to the title of Mr. Burgh's paper, they must all agree that a very fair description had been given of what steam engines were in the year 1851, and of the improvements that had taken place at that time. To go into all the details of this subject would far exceed the limits of a paper; but, nevertheless, it had led to an interesting discussion, and in itself conveyed a great number of valuable details. The question of twin screws was, perhaps, the most important one that had been touched upon, and he agreed with Mr. Grantham that in an ordinary passenger and cargo or mail ship, with considerable draft of water, the single screw would probably give as efficient results in speed and economy of power as the double screw; but where a great amount of power was required to be applied to a

vessel of limited draft, as was the case with blockade runners, the double screw might do more than could have been done with a single one, and he would further express an opinion that, in the manœuvring of ships of war in action, the double screw system, no doubt, conferred many advantages. He might remark, that Captain Selwyn appeared to be a little mistaken with regard to the consumption of fuel. He understood Mr. Burgh to state that the consumption of coal had been reduced from 7 lbs. or 8 lbs. per indicated horse power as low as $2\frac{1}{2}$ lbs. Perhaps the first was rather too large a figure as applicable to ten years ago, but his own impression was that the engines of good makers had worked with a consumption of not more than $1\frac{1}{2}$ lbs. to $1\frac{3}{4}$ lbs. per indicated horse power, which, compared with ten years ago, was a very great saving, and he thought our marine engineers ought to be gratified rather than otherwise, that they had thus far succeeded in economizing fuel. He now begged to propose a vote of thanks to Mr. Burgh for his interesting paper.

The vote of thanks having been passed,

Mr. Burgh acknowledged the compliment, and in reply upon the discussion, said he thought the advantages of the twin-screw system was principally connected with the facilities for steering. With regard to the size of ship to which that system should be limited, it was impossible to lay down any rule, because it must be borne in mind that it was more than probable that very heavy ordnance would be brought into use on ship-board, so that very large vessels would become necessary, and then increased steerage power would be most valuable. The problem to be solved was whether the twin-screw system admitted of universal application regardless of size and other conditions. Of that, he repeated, he required more evidence than had as yet been presented to him. With regard to the question that had been asked as to whether the accumulation of scale in the boiler had been prevented, he would say if they used proper water in the boiler when they commenced working it, and if they took a sufficient supply of it to obviate the necessity of using dirty salt water, employing, at the same time, surface condensers, the scale in the boilers would be very greatly reduced. In reply to Mr. Wilson, he would say, he thought the water was generally taken from the condensers, where but very little oil was presumed to be. Sometimes, it was true, in lubricating the internal portion of the cylinders, a certain portion of oil would get into the condensers, but not to an extent likely to prove injurious to the boiler.

At the conclusion of his remarks, Mr. Burgh explained the action of the equilibrium slide-valve, and described the models and drawings lent by the several firms named in the paper, to whom the thanks of the Society are due.

Peculiarities of Indian Engineering. By MAJOR J. G. MEDLEY, R.E.

From the London Civil Engineer and Architect's Journal, August, 1865.

In this paper I propose to draw attention to some of those peculiarities in Indian engineering, which will serve to show the conditions under which work has to be executed in this country, (India,) and how far they differ from English methods. The sketch will not, perhaps, be altogether destitute of interest to many who are in India.

First, as to the agency. Except forts, arsenals, dockyards, barracks, and the like, there is scarcely a single public work in England in which the Imperial Government is directly interested; for even such works as jails, roads, &c., belong to the counties, or to recognised local interests, while the great mass of important works, such as railways, harbors, &c., belong to joint stock companies, and are private property.

In India, the government is the constructor and maintainer of nearly every public work throughout the country. Not merely works which specially appertain to an immense military establishment, but every road, bridge, church, court-house, jail, &c., has to be built from Imperial funds, and through government officers. Nor can even the railways be excepted, for, though the capital employed is not its own, yet the controlling power possessed by government is so great,* that not the smallest work can be undertaken, nor the salary of the least official paid, without its written authority.

For the above work, a great department of state, the Department of Public Works, is specially provided, by which a systematic control is maintained over a vast body of officials, European and native, acting as engineers, overseers, &c., from the secretariat down to the meanest employee.

But another distinctive difference between the agencies employed in England and India is, that in the former country, work is executed almost invariably by contract, while in the latter, daily labor employed and paid by the engineers is as invariably used. It is true that every effort is being made to introduce the contract system, and that it is generally in vogue in the presidency towns, and on most of the great railway works, but over the whole country the vast mass of the government work is done by daily paid labor, and the extra work thereby thrown upon an engineer may be easily conceived.

In another very important matter do the functions of the Indian engineer differ much from his brother in England. In many parts of the country there is no organization of labor whatever, and, when works have to be executed, the engineer has to collect and train his

* This arises from the guarantee system under which the capital has been raised, the government guaranteeing a minimum rate of interest (5 per cent.) to the share holders on all sums passed to capital account. The controlling power is exercised through the government consulting engineers, who have a veto on almost every action of the company's engineers. The system, though perhaps the best that could be devised at the time, has been productive of much delay and no little dissension. It would be a preferable course for government to grant a certain subsidy to the railway company for every mile of line, as completed and open for traffic, and some such arrangement will probably be adopted in future.

workmen, to make arrangements for carriage,* to make his own bricks, burn his own lime, cut his own timber, and, in a word, superintend a hundred petty details, which, in a civilized country, are undertaken by a hundred different men, each skilled in his own peculiar business.

Of the workmen themselves, much good may be said. That they have the usual prejudices of ignorant men to the introduction of new ideas, and new methods of working, is to be expected, but they are not worse than others in that respect, and if well managed are, as a rule, both intelligent and teachable. Excellent masons, carpenters, and smiths abound in the country. The machinery in the various railway workshops is managed by natives under European superintendence, and though there are no native engine drivers as yet, we shall doubtless have some before long.†

The most striking thing to the engineer fresh from England is the total absence of the ordinary mechanical appliances for executing work. Vast earthworks are still made by the help of the phourah, or native spade, and baskets carried on the heads of women and children. Wheelbarrows are scarcely ever seen ; horse carts still more rarely. For getting water out of foundations, &c., pumps are coming into use, but in general, the primitive native modes of baling, or the churus (leather bag,) or Persian wheel worked by bullocks, are still employed. Bricks and tiles are almost invariably hand-made, and the pug-mill unknown; the saw pit is never used.

Of course, the principal reason for this is the comparative cheapness of labor, but if the rate of labor increases for a few years longer, as it has done for some time past, the introduction of more elaborate appliances will become essential. At present, except the railway workshops and those established at Roorkee, there is no steam machinery in the country, unless at the presidency towns. Machines driven by wind power are also unknown ; it is difficult to say why. Of the enormous water power available on the numerous canals and rivers, very little is utilized. Sawing machines are here and there put up, and

* This difficulty of carriage alone, in a country where the distances are so vast, and the means of intercommunication so incomplete, is most serious. The greater portion of the permanent way of East Indian Railway, was brought by native boats up the Ganges, and £100,000 worth of rails, &c., now lie at the bottom of that river. On the Punjab Railway, the materials were brought in boats up the Indus, which were often seven months on the voyage, (800 miles,) the cost of freight between Kurrachee and Moulton being double the freight from England to Kurrachee. The locomotives after getting to Moulton, were dragged up an unmetalled road to Lahore on trucks, by elephants and bullocks—six weeks being occupied in accomplishing the 200 miles. On this line too, which runs through a desert, the first steps of the engineers were to dig wells and build huts for the work-people, and induce grain merchants to live in the desert to supply their wants. When the writer went down to inspect the first trace of the line with the chief engineer, water and provisions had to be carried on camels to supply the whole party.

† In the railway workshops at Lahore, a short time ago, I saw the carpenters working at regular benches instead of in their own squatting position and turning out some beautiful specimens of work. The whole of the rolling stock (except the iron work, which is brought from England) has been made at Lahore for this line by native workmen. At Goojranwalla I saw a Colt's revolver, copied so exactly, even to the engraving on the cylinders, that only very close inspection could tell it had been made by a native smith.

the common punchukkee, or native corn mill, is everywhere seen where there is an available fall. Machinery worked by animal power is confined to water raising for irrigation purposes, and to one or two primitive inventions employed in manufactures.

Having said so much of the agency employed, let us glance at the materials used, and the works turned out. In Central India and the hilly districts all over the Continent, many varieties of excellent building stone exist, and are abundantly used. In the great plains of Bengal, Hindostan, and the Punjab, however, brick is the only available material. The English sized bricks, or those of a still larger size, are now coming into general use. The native bricks are very small, excellently burnt, laid with little attention to bond, and with a profuse expenditure of mortar. Bricks are burnt with wood fuel,* in kilns of several kinds; or in stacks like English clamps, with dried cow-dung instead of coal.

Excellent lime is everywhere abundant, produced either from limestone, *in situ*, or the boulders found in hill torrents, or the kunker found in the plains. It is mixed with various substances for mortars, of which pit sand and soorkhee (pounded brick) are the chief ingredients. For very strong or fine mortars, coarse sugar and egg shells are sometimes added.

A great variety of fine timber is found in India, generally brought from the forests in the hills—among which may be noticed saul, a dark, heavy, straight, and strong wood, and deodar, nearly the same as the cedar of Lebanon; the former used in the North West Provinces, the latter in the Punjab for every kind of building purpose. Both of these are found in the hills alone, at an elevation of from 2000 to 5000 feet; the trees are cut down and thrown into the rivers, and when these rise, the logs are floated down to the plains. In West and South India, teak is in general use. It abounds in the forests of Burmah, being one of the most valuable productions of that Province. Toon, an inferior sort of mahogony, is extensively used for furniture; sissoo or sheeshum, and some of the varieties of acacia, are hard, heavy, crooked woods used for strength and toughness.

Iron ores of fine quality are abundant in many parts of India, but from the want of fuel and carriage are little worked, and English iron is generally used. Government have made, and are now making, several praiseworthy attempts to develop the manufacture of iron.

Here it may be as well to note one or two specialities of construction employed in India.

In roads, stone metalling, laid as in macadamised roads, is common enough, but in the great plains of Upper India the peculiar material kunkur is used, and laid in a peculiar manner. It is a species of concretionary oolitic limestone, found in beds close to the surface, and has to be drenched with water, rammed quite smooth, and then suffered to dry before any traffic is admitted. It then makes a white,

* Except in a few places where coal is found. No coal worth working has yet been discovered in Northern India. The locomotives burn wood, and fuel is scarce and dear.

smooth, and very excellent road covering. In Southern India, laterite and moorum, a sort of red gravel, are commonly employed.

In foundations, piles are rarely employed, for so many destructive agencies are at work that they would not be lasting. The majority of the water courses are nearly dry at one time of the year, and this affords great facilities for getting in the foundations of bridges or other works in the water. For these, the general substitutes for piles are masonry wells or blocks, which are sunk close together, arched over, and on them the piers and abutments are raised; they are also used as foundations for houses in places where the soil is very treacherous. The beds of most rivers in Northern India when bored, show sand to an immense depth. In Bengal alluvial mud is found to as great a depth, and necessitates as much precaution as sand. The dry state of the river beds also gives great facilities for turning arches without the use of expensive centerings. A simple arrangement of dry bricks and timbers are constantly used, built up in the bed of the stream; of course the work is subject to accidents from sudden floods, but these are very rare.

The greatest works as yet executed in India belong, as in England, to the railways. Indeed there are none in the world more interesting or important than the Bhore Ghaut Incline, the Soane and the Jumna Bridges, and other works little inferior to them which might be enumerated. The East Indian Railway, 1000 miles long from Calcutta to Delhi, with the branch to Jubbulpore now under construction, is probably the longest line in the world owned by a single company, as it is certainly one of the greatest triumphs of engineering. The Great Indian Peninsular, and other lines, though inferior in length, are some of them, at least, of equal engineering interest.

With them may be classed the great roads, though the system like that of the railways, is still far from complete. The Grand Trunk Road from Calcutta to Lahore, 1300 miles in length, comprises every variety of construction, from the heavy gradients through the Rajmahal hills, to the massive and level embankments between the Jumna and Sutlej. The Lahore and Peshawur road, a continuation of the Trunk line, 270 miles long, and now rapidly approaching completion, may challenge comparison with any in the world; while, in the formidable extent of drainage crossed by it, it probably stands alone. Of others, the Hindostan and Thibet road, when finished, may take its place by the side of any of the famous Alpine roads; while the great Deccan road, the Assam road, and many others still in hand, are works of considerable magnitude.

Besides the length of the distances to be traversed, it is in the formidable character of the flood waters that have to be crossed that the specialities of their construction are to be sought. Nothing but actual experience will convince the English engineer of the enormous waterway required to pass drainage lines, which, seen only in the dry season, are so shallow and often perfectly dry; and scarcely a season passes without the most ample experience being set at naught by the results of some extraordinary flood. The Indus has been known to

rise 50 feet in a single night, where confined between its rocky banks at Attock. At a distance of 800 miles from its mouth, I have been in a boat in the middle, and was unable to descry either shore, while the deep channel in one single season has shifted its place laterally as much as three miles. Cross this river in the dry season, and the track lies over ten miles of quicksand and mud, while a channel of 1000 feet in width passes the whole body of water. To carry a road across the valley of such a river, and to bridge such a stream, may well daunt the boldest engineer.

This describes the rivers of Northern India only; those of Southern and Central India have also their peculiarities, which it would be tedious to detail here.

It is, however, in the great irrigation works that have been or are being constructed in India, that the peculiarities of Indian engineering are more especially to be sought; for, except in Italy, those works have no counterpart in Europe. The Ganges canal, 900 miles long with its branches, and pouring its waters over a million of acres through 3000 miles of distributing channels; the East and West Jumna canals, 200 and 500 miles long, respectfully; the Baree Doab canal, also 200 miles in length, are works of which any country may be proud, and in the principles and construction of which engineers have to learn much which they cannot be taught in England. An entirely separate class of works are the great weirs and tanks of Madras, whereof the works on the Godavery are the finest examples, and which are also purely Indian specialities.

Next, a word may be said as to Indian architecture. The architect and engineer are generally one, and he also is the constructor as well as designer. The requirements of the climate, necessitates modes of construction differing from those in England, but until lately we have not managed to combine coolness and ventilation with much architectural beauty. A reform in this respect is, however, in progress. We are at least erecting handsomer buildings, and attention is being directed towards cooling them effectually. The difficulties are great, for what does for the moist heat of the Lower Provinces, will not answer for the fierce dry heat of Upper India, which it is necessary to exclude for many months all day long, unless the air is artificially cooled before being admitted.* Moreover, the cold in the winter is often excessive, the average extreme range of the thermometer between summer and winter being fully 100 degrees in the Punjab, while in Bengal the temperature is much more equable, the range not exceeding 70°. With all these drawbacks, however, many fine public buildings have been completed, many more are being constructed and projected, and churches, railway stations, and government offices are rising fast, which would do no discredit to any capital.

Some specialities of construction which are common to most Indian buildings attract the attentions of the new comer. Except in the presidency towns, they have no upper story, partly from considerations

* The temperature of the air at midnight in Upper India during the months of May and June, is often over 10J°.

of expense and partly because the upper rooms get very hot during the dry months. The roofs are either thatched or tiled, or else are flat and covered with brick and lime plaster. The thick beams supporting the roof are, as a rule, left exposed below, as ceiling cloths are apt to harbor vermin and conceal the depredations of white ants. The room walls are very rarely papered, being usually plastered and white-washed. Wooden floors would be too perishable and dear, so floors of flat tiles, or of lime plaster are substituted. Doors are numerous, and invariably double, opening in the middle. Verandahs all round a house are considered indispensable.

In many of the most important and interesting branches of engineering little has been done as yet in India; in drainage, water supply, and gas-lighting, we are now only making a commencement even in the presidency towns. A fine scheme, however, is in progress for the drainage of Calcutta, and a similar project will shortly be submitted for Madras, while the drainage and conservancy of native towns and European cantonments are engaging much attention.

In the improvement of our great rivers for inland navigation, little or nothing has been done, but many navigable canals are at work in Madras and Bengal, and others are in progress. In Bengal inundations from the sea and rivers have also given us practice in the important subject of embankments; and the Hidgelee sea dyke, when completed, will, it is said, be a noble work.

Of military engineering not much has to be said. Like the Romans of old, we encamp our troops in the open, instead of shutting them up in forts. Our arsenals are for the most part inside old native forts slightly improved, and, except Fort William and the outposts of our N. W. frontier, there is scarcely a single fort of modern construction in the country.

Closely allied as it is to engineering, a word must be said in praise of that noble work, the Indian Survey, of which too little is known to the scientific world. While the trigonometrical department is covering the country with a net-work of triangles, fixing the position of principal stations with an accuracy that has not been surpassed (if it has been equalled) in the European country,* the topographical department is busy in delineating the features of the mountain districts in a series of maps,† whose fidelity is only equalled by the difficulties which have attended their completion, and the revenue department is mapping the plains to a degree of detail which shows not only every village, but every field in each village.

Incomplete as this summary has been, I will hope that it may be useful in arousing some interest in England in the peculiarities of Indian engineering.

* The Superintendent G. T. Survey, Major Walker, has lately proceeded to Europe to confer with the Russian Government on the means of connecting the great series of Indian triangles with that of the Russian Survey.

† The map of Cashmere lately completed by Captain Montgomerie, R. E., has elicited the warm approval of the distinguished president of the Royal Geographical Society. Many of the trigonometrical stations were above the line of perpetual snow, where the surveyors had to stay for days together waiting for favorable weather for their observations.

MECHANICS, PHYSICS, AND CHEMISTRY.

On Weldless Tires, Circular Rolling, and Railway Wheels.
By Mr. F. J. Bramwell.

From the London Athenæum, September, 1865.

The writer gave an account of the mode of making tire hoops for railway wheels, prior to the invention of weldless tires, and pointed out that such mode consisted in bending a straight tire bar into a hooped form, the ends of the bar having been previously prepared, (if the weld were any other than a "butt" weld,) and then in uniting these ends together by welding, in one of the methods known as the "scarf" weld, or the "double V," or the "bird's mouth," or the "single V." Each one of these weld's required the operation to be performed when the tire was removed from the fire, and therefore not subjected to the full effect of the heat. All these methods were objectionable for other reasons; the "scarf" and the "bird's mouth" welds, because their edges were liable to be burnt; the "double" and "single V," because each required two lines to be made round instead of one. The "butt" weld, as it did not require any great preparation of the ends, admitted of the bar being delivered by the tire manufacturer in a hooped form, by which an economy was effected, inasmuch as the tire manufacturer bent the bar while hot from the rolling mill, and the weld was effected while the tire was actually in the fire, thus enabling the full advantage to be taken of the heat, and means were employed by which a clear surface was obtained, and only one line of weld had to be made sound. Though he (Mr. Bramwell) thought this form of weld the best, yet even that was a source of risk. The writer then proceeded to describe the process of "blocking" the welded tires, in order to stretch them to uniform sizes, as well as test their soundness, alluding to the operation of shrinking the tire on the wheel centre, either preceded or not by a boring process, the fastening on of the tire, and the completion of the wheel by turning the interior. The writer then proceeded to give a description of the mode in which, in the year 1844, he proposed to make tires without a joint weld, now known as weldless tires. This consisted in winding a long bar of iron into a helical coil, of very nearly the size and shape of the required finished tire hoop, and then in placing this coil in a circular furnace, having an opening or "gash" of the form of the sector of a circle, when seen on plan such sector subtending about 60° or 90°, and having placed within it a quick going mechanical hammer, provided with tools of nearly the shape of the finished tire, and adapted to operate on that portion of the hoop that lay out of the furnace and in the sector. By this means the writer proposed to weld the whole circumference of the coil by bringing welding hot portions successively out of the interior of the furnace in the sector-shaped gash. The writer proposed to finish off the ring forging thus made by means of the circular rolling machine which had been invented by Mr. Bodmer in the year 1839, and which, so far as the writer knew, was the first machine ever devised by which the continuous or "cir-

cular" rolling of a ring could be effected. The writer pointed out that Mr. Bodmer did not propose to make a weldless ring; but, on the contrary, intended to make that ring by welding together the ends of a bar, and that the object of his invention was to finish tires by rolling, instead of turning them in a lathe. The writer then stated that though, between the years 1844 and 1855, some few persons brought forward propositions for making weldless tires, nothing really was done, so far as he knew, between those dates in the way of manufacturing them. In the latter year, the writer made a proposition on the subject to Mr. W. Owen, of Rotherham, a large manufacturer of railway wheels, who, after a long consideration, commenced to make weldless tires in the year 1861. The Blaenavon Company commenced their manufacture about the same period. Prior to that time, viz: in 1856, the manufacture of these tires was commenced by Jackson, Petit, & Gauded, in France. Mr. Owen and the Limited Company who had succeeded him, had carried out the making of weldless tires to a very large extent, using machinery nearly the whole of which had been designed by the writer. At present, only very few mills were working upon the same plan, but several were preparing machinery for the purpose. The paper then described the process of making weldless tires, as adopted by the Owen Company. It consisted of making a helical coil of about half the diameter and three times the width of the intended tire, the heating of this coil in a furnace, and then putting it into a mould on the anvil of a steam hammer, and (by the action of the top tool upon it) welding it into a ring blank, about half the diameter and twice the thickness of the finished tire. The process is finished by the removal of this block to a circular rolling machine, on Bodmer's principle, but combined with hydraulic power of such character as to be capable of rolling out the tire to its proper decreased thickness and increased diameter. The paper then went on to show that not only is the manufacture of weldless hoops completed by circular rolling one that insures soundness and safety, but also, in consequence of dispensing with the "crop ends," and of the passing backwards and forwards of the bar whilst being rolled, both of which accompany and are drawbacks to ordinary rolling, such manufacture of weldless hoops is really an economical mode, and may be advantageously employed in the manufacture of all heavy straight bars, rails, and plates, which would in the first instance be rolled into the ring form, and then that ring being cut through would be got by flattening it out in the same way that sheets of glass were made by laying open the cylinder into which the glass was first formed. The paper pointed out how beneficial the use of weldless rings would be for boiler work, as they would dispense with the longitudinal seams, which were the source of weakness in boilers. The paper then described the improvement in manufacturing solid wrought iron wheel centres invented by M. Arbel, of France, and practiced by the Owen Company. It consisted of putting together the various parts forming the ring, spokes, and boss, and heating the same in a furnace, from which they were removed into a die, to be welded by the action of a powerful hammer, having (when its moving parts

were fitted so as to make the centres of engine wheels) a weight of more than twenty-five tons, and a maximum drop of six feet. The paper then described a common kind of wheel centre in very general use, wherein wrought iron spokes were combined with a cast iron boss, and pointed out the objection to this mode. It then stated the improvement of M. Lahousse, of Belgium, as practised by the Owen Company, by which the advantage of a wrought iron boss can be obtained at a rate as economical as that of a cast iron boss, and showed that this was done by enveloping cold or moderately heated wrought iron spokes in the highly plastic halves of a welding hot wrought boss, by which the spokes were firmly embraced and held fast. The paper concluded by expressing the conviction, on the part of the writer, that on account of the greater safety of weldless tires, they would come into universal use, and that, though the conservatism arising from the investment of capital in machinery, which would be displaced by a new invention, might delay its general adoption, the force of public opinion would, in the end, set aside the present process of manufacture, and lead to the adoption of that he described.

Mr. R. Mallet, described a process of producing the "butt" weld by rubbing the ends together, introduced some years ago, and asked why it was abandoned.

Mr. Bramwell believed that it was found impossible to adjust the motion and stop it exactly at the right instant required, as the temperature fell.

Mr. Siemens spoke in terms of approval of Mr. Bramwell's process. He said it seemed to open out a new field in the application of iron and steel. He thought, ultimately, makers would adopt the plan of rolling iron in a circular form and then opening it.

Sir. W. Armstrong said that many important ideas had been brought before the meeting in Mr. Bramwell's paper, which, he had no doubt, would, in due time, be attended with very important results. As regarded the mode of manufacturing wrought iron rings, he looked with great favor on Mr. Bramwell's mode of constructing the weld by forming it first into a coil. It was a method which he (Sir W. Armstrong) had always advocated in the construction of guns; the advantage being that they got the welds into a longitudinal instead of a transverse direction.

On some Developments of and Improvements in Giffard's Injector. By Mr. J. Robinson.

From the London Athenæum, September, 1865.

Having referred to the difference of opinion existing among engineers as to this, which had been called by the President, somewhat paradoxical instrument, the paper described the action of the injector to be as follows: Steam was taken from the steam space of any boiler by means of the injector, the water supply was brought into contact with the steam current, and the result in the shape of hot water was

passed into the water space of the boiler. The question was, now, having an equal pressure on all parts of the boiler, did a fluid not only pass in the shape of a current from one part to another, but at the same time carry with it another fluid exposed to atmospheric pressure only. The author propounded the following explanation of the instrument: Advantage is taken of the superior velocity at which a steam current issues from a boiler over that of a water current issuing from a boiler at the same pressure. These velocities are assumed to bear an exact proportion to the densities of the two fluids. The steam current, having but a small amount of momentum, the water supply is brought into contact with it, and two results follow: first, the steam current is incorporated with the water current by the condensation of the former; secondly, an amount of the velocity of the steam current is imparted to the water current in proportion of the quantities of each which are brought together in the combined jet. As the weight of steam issuing from an opening is exactly equal to the weight of water which would, under the like pressure, issue from the same opening in the same time, the area for the admission of steam to the injector is made greater than the area of the pipe which receives the condensed jet for transmission to the boiler, as otherwise the amount of the velocity imparted to the water current would not be sufficient to overcome the velocity of the resisting current from the boiler. The combination of the foregoing principles and arrangements in the injector is so effective that, with steam at a pressure of 30 lbs. above the atmosphere, water can be forced into a boiler containing steam of very nearly double that pressure. Having described the construction of the injector, the paper pointed out the importance of an apparatus capable of supplying water to steam boilers without motion of any of its parts, and independent of the engine connected with it. It has proved almost essential to some particular arrangements of boilers and engines. For locomotives, the advantage had been very considerable, inasmuch as it was most important that the machinery of engines running at such a high velocity should be free from the apparatus and repairs necessary when their boilers were fed by pumps worked by the engine. The advantage, also, was obtained of feeding the boiler while the locomotive was at rest, either in the station or during its retention in a siding, waiting for the line to be cleared. For this purpose, 5230 of the injectors had been manufactured in this country. For stationary boilers the injector had been found convenient, because of the saving of the pipes and other communication from the boiler to the engine room, the suppression of the pumps and the parts of the engine necessary to work them, and the advantage of being able to fill up the boilers during meal hours, and at other times when the engine was stopped. For this purpose, 3816 had been made in this country. For marine boilers the apparatus was most convenient, since it answered generally the purpose both of the main engine pumps and the donkey pumps, and brought the control of the feeding apparatus within the reach of the stokers, without reference to the engine room, and without the noise and complication of the donkey pump. In a simple form, and also in the ordinary injec-

tor arrangements, the principle had been applied for raising water from mines and wells, the inducement being the cheapness and simplicity of the apparatus, and the small space and easy manipulation required. The paper proceeded to describe in detail improvements which had been made upon the injector as it first came from the hand of the inventor; but these cannot be made clear without a reference to diagrams.

Mr. F. J. Bramwell said he would endeavor to explain the action of this apparently paradoxical instrument. He would ask the meeting to imagine two deep cisterns placed side by side, and with only a narrow space between them, and that in each near the bottom there was made an opening, these openings being exactly opposite the one to the other, and that one of the cisterns was filled with water while the other was empty, or, at all events, had not any water above the opening. In this condition of things, it was clear that a jet would issue from the opening in the side of the full cistern, would shoot across the narrow space between the two cisterns, and would enter the empty cistern at the aperture opposite to the one by which the jet had issued. Now, it was easy to believe that, not only might the jet enter if the receiving cistern were empty, but that it might even do so if the receiving cistern had water in it above the level of the opening so long as that were not so high (nor nearly so high) as that in the cistern from which the jet issued; and it appeared by experiment that if the water in the receiving cistern were not more than one-seventh of the height of that in the discharging cistern, the whole of the jet would be capable of entering the receiving cistern; and he (Mr. Bramwell) could well believe this, as he had found by actual experiment that when the water in the receiving cistern was one-half the height of that producing the jet, still 83 per cent. of all the water went in. He, therefore, thought the meeting might take it as established, that if there were a cistern containing 7 feet of water above an orifice in its side from which a jet issued, and that orifice were placed opposite and near to another orifice in the side of a cistern in which there was only one foot of water above this orifice, that the whole of the jet from the vessel containing 7 feet would run into and be received by the cistern containing the opposing amount of one foot depth of water. Let the meeting then imagine the cisterns having the same height of water in one as in the other, and he would ask them to imagine that a jet of water was issuing from the one, and was shooting across the space towards the other cistern; and he would ask them to assume that, by some magical means, that water was, in its passage across the space, converted into an equal weight (not an equal volume) of mercury. The result would be, in round numbers, that the jet when it reached the opposing cistern would be only one-fourth of the size of that which left the discharging cistern: so that a given weight of water, which issued from an orifice of fourteen square inches in the side of the discharging cistern, would (if it could in its passage across the space be converted into mercury) be capable of entering the receiving cistern through an orifice containing only one square inch. But if this could be accomplished, it would be mani-

fest there would be *concentrated* on one square inch the whole momentum which had issued from fourteen square inches; and, therefore, it was clear that if a concentration of seven times was sufficient to cause a jet to enter, a concentration of fourteen times was much more than sufficient. Of course, this assumption, that an issuing jet of water could be *concentrated* by being in its passage turned into mercury, was impossible; but, let the meeting consider the issuing jet to be that which it really was in the injector, viz: steam, and imagine this jet in its passage from the discharging orifice to the receiving orifice was condensed by an application of cold surfaces, then, indeed, there would be produced a concentration far greater than the fourteen times spoken of as taking place if the water were turned into mercury, and that would be the concentration due to the relation that equal weights of steam and water bore to each other. This, of course would vary according to the pressure of the steam, but it might be 1000 or more, or 800, or 400, or 200, according as the boiler from which the jet issued was working with low or high steam; but, even assuming the steam was so high that the concentration, when it was turned into water, was only 200 times; nevertheless, this would follow, that the jet of steam that required an opening of an area of 200 to escape from, would be capable, when condensed into water, of re-entering by an opening of an area of 1, and that, therefore, the concentration of force would be 200 times, and there could be no doubt whatever that this would be sufficient, and far more than sufficient, to enable the jet of steam that had issued from a boiler to return, in its condensed form, into that boiler. But if this were all that the apparatus could do, it was evident that it would be of no practical use; and he proceeded to explain how the instrument was capable of taking into the boiler other water along with that arising from the condensation of the steam. If the force were concentrated 200 times, it was, undoubtedly, much more than required. The issuing jet of steam was not merely condensed by an application of cold surfaces, but was, as is well known, condensed by suffering it to come in contact with a stream of the feed water; which, as it condensed the steam, became mixed with it so that the condensing water and the condensed steam flowed forward as one stream; but as this stream was now not merely composed of the water of the condensed steam, but also of that which condensed it, it followed that the degree of concentration was diminished, and, to an extent, depending on the amount of water which had been employed to condense the steam. If nine parts had been used, then the concentration, in lieu of being 200 times, would be twenty times, because the original one part and the nine together made ten parts in lieu of one, and therefore diminished the concentration to one-tenth of that which it was before, and if nineteen parts were used, then the concentration would only be ten times, and so on; it was self-evident that the water resulting from the condensation of the steam would possess so much surplus concentration, that it is clear it would be capable of taking with it several times its own weight of water before that concentration was reduced so far as to be unable to cause the jet to re-enter into the boiler or vessel from which it had proceeded.

At a recent discussion in London it had been stated the French engineers were of opinion that one-third of the entering jet must be uncondensed steam. He (Mr. Bramwell) believed this was an entire error, and he would ask the meeting to allow him to repeat to them an illustration which he had used at the meeting of the Mechanical Engineers, when Mr. Robinson first brought forward the subject there about six years ago, and that was to refer again to the cistern he had imagined, and to assume that there was in its side a valve opening inwards, but kept shut by the pressure of the water within, and that a person standing opposite to the cistern were to throw a steel bolt of a given weight with a certain velocity against the valve, it could readily be understood that the bolt might force open the valve and enter the cistern. Next, assume that an equal weight of steel were made into a spiral spring of the same diameter, but double the length of the bolt, and assume that this were thrown with a similar velocity to that used in the first instance against the valve, it might in this case also be understood that then, although there was the same weight of steel striking the valve with equal velocity, it might be unable to dash it open, because a large part of the momentum would be consumed in causing the spring to collapse, and thus the object of opening the valve might be frustrated. He (Mr. Bramwell) thought that this illustration showed how important it was that all the steam should be condensed, because steam being, as is well known, an elastic fluid, any uncondensed portion that formed part of the entering stream would act in the manner of the spring just mentioned, and, therefore, would be prejudicial to the efficient working of the injector.

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*On the Manufacture of Cast Steel, its Progress, and Employment as a Substitute for Wrought Iron.** By Henry Bessemer.

From the Civil Engineer and Architect's Journal, October, 1865.

On the 13th of August, 1856, the author had the honor of reading a paper before the Mechanical Section of the British Association at Cheltenham. This paper, entitled "The Manufacture of Malleable Iron and Steel without Fuel," was the first account that appeared, shadowing forth the important manufacture now generally known as the Bessemer process.

It was only through the earnest solicitation of Mr. George Rennie, the then President of the Mechanical Section of this Association, that the invention was at that early stage of its development, thus prominently brought forward; and when the author reflects on the amount of labor and the expenditure of time and money that were found to be still necessary before any commercial results from the working of the process were obtained, he has no doubt whatever but that, if the paper at Cheltenham had not then been read, the important system of manufacture to which it gave rise, would to this hour have been wholly unknown.

In the original fixed converting vessel, as patented and erected in

* Read before the British Association.

London for experimental purposes in 1856, the tuyeres were passed through the side of the vessel in a horizontal direction. The result was, that the blast of air entered only a short distance into the fluid mass, and much of it escaped upwards between the sides of the vessel and the metal. The effect of this was the rapid destruction of the brick lining, caused by the excessive temperature generated in the process, and the solvent property of the resulting silicate of protoxide of iron, which sometimes destroyed a lining of half a brick in thickness during the blowing of two charges of metal for about twenty minutes each. Another difficulty arose from the impossibility of stopping the process without running out the metal, for if the blowing ceased for one instant, the fluid metal would run into the tuyeres, and stop them up.

A great inconvenience of the fixed vessel also arose from the danger and difficulty in tapping out the fluid malleable iron with a bar, after the manner of tapping an ordinary cupola furnace, for the blast had to be continued during the whole time the charge was running out of the vessel, in order to prevent the remaining portions from entering the tuyeres. A similar difficulty arose while running in the crude metal from the melting furnace, since it was necessary to turn on the blast before any metal was run into the vessel, the first portions so run in were, in consequence, partially decarbonized before the whole of the crude metal had left the melting furnace.

These were among the most prominent difficulties that had to be remedied. It is, however, satisfactory to know that even in this, its infant state, the process and apparatus were practically successful, in proof of which there is placed upon the table part of a malleable iron railway bar made from pig iron, at Baxter House, by blowing air through it in the apparatus just described, the fluid malleable iron having been run into a 10 inch square ingot mould, and the bloom so made rolled direct into the bar shown. The small malleable iron forged gun will serve as an example of the clearness and freedom from cracks or flaws in malleable iron, so made and forged under the steam hammer. It is one of the very early productions of the process, and, like the malleable iron rail, was made wholly without any recarbonizing of the metal, or the employment of spiegeleisen or manganese in any form whatever. Malleable iron so made from hematite pig iron is red-short, like all other wrought iron made wholly from hematite; but that it is perfectly malleable and extremely tough when cold may be seen on examination of the iron rope exhibited, which consists of four rods of $1\frac{1}{2}$ inch round iron twisted cold into a close coil. These bars extended 13 inches in length in 4 feet, and were reduced nearly $\frac{1}{8}$ inch in diameter, in the operation of twisting, thus showing that malleable iron so made possesses an extraordinary degree of ductility.

It may be remembered that an important part of the process, as described at Cheltenham in 1856, consisted in tapping the fluid crude iron from the blast furnace, and allowing it to flow direct into the converting vessel, and be there blown to the extent only of decarbonizing it so far as to produce cast steel. This part of the original programme has been most successfully carried out in Sweden, where an extensive

establishment for its manufacture has been erected by M. Göranson, of Geffle. The large steel circular saw plate exhibited, is an example of the conversion of crude cast iron run direct from the blast furnace into the converting vessel, and there blown for nine minutes, in which period it had been converted into cast steel of the desired quality, and was then placed into an ingot mould without being recarbonized, and wholly without the employment of spiegeleisen or manganese in any form whatever.

With these few illustrations of capabilities of the process as originally described at Cheltenham, the author will proceed to show how the disadvantages of the old fixed converting vessel were remedied and other improvements introduced. Many forms of converting vessels were tried on the large scale before this desirable object was attained. In some of them the lining was too easily broken down by the violent motion of so heavy a fluid as iron; in some of the forms tried, the angles allowed the metal to solidify them, and so clog up the vessel; in others, the mouth of the vessel being too small, caused the metal to be thrown out by the force of the escaping blast. It was also found that if the mouth was too large the heat escaped, so as to cause part of the converted metal to solidify in the vessel; the relative height and diameter of the vessel was also found to produce important differences in the working of the process; finally, and after many long and expensive trials, the form of vessel shown at B and C was adopted.* This vessel is made in two parts, so as to admit easily of its being lined up with a pulverized silicious stone, known as "ganister," which so resists the action of the heat and slags as to last for fully 100 consecutive charges of steel before it is worn out. Its form is that of the arch in every position which prevents the lining from falling down by its own weight. There are no angles in which the splashes of metal can solidify and accumulate. Its mouth directs the flame and sparks away from the workmen, and from the moulds and other apparatus; while the throat of the vessel, and the position of the mouth, almost entirely prevents the throwing out of the metal. The vessel is mounted on trunions supported on stout pedestals, so that a semi-rotary motion may be communicated to it at pleasure. The tuyeres are placed at the bottom of the vessel, so as to force the air vertically upward through the metal, as shown, without coming in contact with the sides of the vessel. When the crude metal is to be run into the vessel it is turned on its axis nearly into the position shown at C, the mouth being a little higher up; a gutter will then conduct the crude cast iron from the melting furnace into it. It is not necessary to turn on the blast until the whole of the metal is run in, because the tuyeres occupy a position above the level of it. As soon as the air is admitted through the tuyere, the vessel is turned into the position shown at B, when its decarbonization immediately commences. As soon as this is effected as much molten pig iron made from spathose iron ore is added to it as will restore the quantity of carbon necessary to produce the desired quality of steel, which is then run into the casting ladle in the manner shown,

* See the Journal, vol. xxiv., p. 179.

and from whence it is transferred to a series of iron moulds ranged in a semi-circular pit, each mould being placed within the sweep of the casting crane; the filling of these moulds is regulated by a cone valve made of fire clay, and fitted in the bottom of the casting ladle, so as to be opened or shut at pleasure by means of a handle on the outside of the ladle.

It will be readily understood that in the fixed vessel first described any giving way of a fire clay tuyere would stop the process, and cause much inconvenience; but with the movable vessel it is not so, for at any moment of time during the process the vessel may be turned on its axis and the tuyeres raised above the level of the metal; the blast may then be turned off, the tuyere box opened, and the faulty tuyere stopped up or removed, after which the process may be again resumed. The movement of the vessel on its axis, the rise and fall of the casting crane, and the other cranes employed for removing ingots from the casting pit, are all effected by a simple hydraulic apparatus, so that the whole process is under the perfect control of a single operator, placed far away from the heat and showers of splashes that accompany the process.

Up to this period the manufacture of cast steel by the old, as well as the new process, is still so far imperfect that steel of the highest quality cannot be made from inferior iron. In the old Sheffield process the original quality of the Swedish charcoal iron employed governs the quality of the cast steel made; consequently, £36 per ton is freely given for the high class Danamora iron, while other brands of Swedish charcoal iron may be bought for £15. In either case these are expensive raw materials for the cast steel maker.

In 1839, the trade of Sheffield received an enormous impulse from the invention of Josiah Marshall Heath, who patented in this country the employment of metallic manganese, or, as he called it, carburet of manganese. The addition of a small quantity of this metal, say from one-half to one per cent., rendered the inferior coke made irons of this country available for making cast steel; it removed from these inferior qualities of iron their red-shortness, and conferred on the cast steel so made, the property of welding and working soundly under the hammer. This invention was of immense importance to the town of Sheffield, where its value was at once appreciated. Mr. Heath, supposing himself secure in his patent, told his licenses that if they put oxide of manganese and coal tar, or other carbonaceous matter, into their crucibles along with the blister steel, that it would do as well and be much cheaper than the carburet of manganese he was selling them; in effect it was the same thing, for before the steel was melted, the carbon present reduced the manganese to the metallic state, so that his patent carburet of manganese was formed in the crucible in readiness to unite with the steel as soon as it became perfectly fused. But the law decided that this was not Heath's patent, and so the good people of Sheffield, after many years of litigation, were allowed to use it without remuneration to the inventor.

Manganese has now been used for many years in every cast steel

works in Europe. It matters not how cast steel is made, since manganese added to it necessarily produces the same beneficial changes; no one better appreciated this fact than the unfortunate Mr. Heath, as evidenced by his patent of 1839, in which he declares that his invention consists in "the use of carburet of manganese in any process whereby iron is converted into cast steel." Had Heath seen in his own day the Bessemer process in operation, he could not have said more; he well knew the effect produced by manganese on steel, and, therefore, claimed its employment in any process whereby iron is converted into cast steel.

With this patent of Heath's expired and become public property, coupled with the universal addition of manganese and carbon to cast steel, it would naturally be supposed that the author, in common with the rest of mankind, would have been allowed to share the benefits which Heath's invention had conferred on the whole community, but it was not so.

The reading of the author's paper at Cheltenham in 1856, was, by the powerful agency of the press, communicated in a few days to the whole country. Great expectations of the value of the new process formed, both by scientific and practical men, in proof of which it may be stated that licenses to manufacture malleable iron under the patent were purchased by iron masters to the extent of £25,000 in less than twenty-five days from the reading of the Cheltenham paper. Great excitement existed at that moment in the iron trade, and many persons seemed to covet a share in an invention that promised so much; there was, consequently, a general rush to the patent office, each one intent on securing his supposed improvement. It was thought scarcely possible that the original inventor should, at the very outset, have secured in his patents all that was necessary to the success of so entirely novel a system, he must surely have overlooked or forgotten something; perhaps even left out all mention of some ordinary appliance too well understood to really need mentioning; so in the jostle and hurry to secure something, any point on which a future claim could be reared, was at once patented. Some of these gentlemen even re-patented portions of the writer's own patents, while others, patented things in daily use, in the hope that they might be considered new when added to the products of the new process.

Within six weeks of the date of the Cheltenham paper, Mr. Robert Mushet had taken out three patents, which form part of that long series of patents by which he hoped to secure to himself the sole right to employ manganese in combination with iron or steel made from pig iron, by forcing atmospheric air through it. In this long series of patents almost every conceivable mode of introducing manganese into the metal is sought to be secured. It was claimed if used in combination with pitch, or other carbonaceous matter; it was claimed if simply used in the metallic form, or, as Mr. Heath calls it, a carburet of manganese; it was also claimed if combined with iron and carbon—as in spiegeleisen. Manganese, in any of these states of combination, was claimed if put in with the metal prior to the commencement of the

process; it was claimed if put in during the continuation of the process, and claimed if added to the steel after the process had been completed; it was also claimed if put into any furnace, crucible, or vessel, that the converted metal might be run or poured into; in fact, manganese and its compounds were so claimed under all imaginable conditions, that if this series of patents could have been sustained in law it would have been utterly impossible for the author to have employed manganese with steel made by his process, although it was considered by the trade to be impossibe to make steel from a coke-made iron without it.

In the *Mining Journal*, of September 24th, 1853, just four years before the first of Mr. Mushet's series of patents, a letter was published on the subject of Heath's invention. The writer of that letter says: "I am a steel maker, and deny that steel was ever made with the addition of carbon and manganese or carburet of manganese previously to Heath's invention, and I confidentally assert that no cast steel maker can now carry on his business to profit without the aid of carburet of manganese." "There are," he says, "a hundred methods of improving steel with manganese, but they all involve the same principle. Put carbon and manganese into the steel pot in any form you please, and at any time you like, and if the steel be thoroughly melted the carburet of manganese melts also and is alloyed, and the improvement is unerringly effected, and by the use, in every instance, of carburet of manganese."

This letter clearly shows how well the subject was understood in the steel trade thirteen years ago.

Very soon after the reading of the Cheltenham papers, several rough trials of the Bessemer process were made privately by persons in the iron trade, and defects discovered which were supposed by practical men to be perfectly fatal to the invention. Once more the press teemed with accounts of the process, but this time it spoke only of its utter impracticability, and of regrets that the expectations originally formed were so fallacious. The storm, however, gradually subsided, and the process and its author were soon entirely forgotten. Imperfections in the process there certainly were, but the author had had the most irrefragable proofs of the correctness of the theory on which his invention was based, and also that the reasoning on which it was so utterly condemned by the trade was in itself wholly fallacious; he, therefore, decided not to argue the question against a hundred pens, but to energetically prosecute his experiments, and to remain silent until he could bring the process to a commercial success. When, at the expiration of about three years of incessant labor on the part of himself and partner, Mr. Longsdon, and an expenditure of more than £10,000, the process was again brought before the public, not the slightest interest was manifested by the trade; it had been for years agreed on all sides that it was a total failure, and was looked upon simply as a brilliant meteor that had suddenly flitted across the scientific horizon, leaving the subject in more palpable darkness than before. This entire want of confidence on the part of the trade was most discouraging;

one of two things became imperative, either the invention must be abandoned, or the writer must become a steel manufacturer; the latter alternative was unhesitatingly accepted, and Messrs. Henry Bessemer & Co. determined to erect a steel works at Sheffield, in the very heart of that stronghold of steel making. At these works the process has ever since been successfully carried on; it has become a school where dozens of practical steel makers received their first lessons in the new art, and is the germ from which the process has spread into every state in Europe, as well as to India and America.

By the time the new works at Sheffield had got into practical operation, the invention had sunk so low in public estimation that it was not thought worth paying the £50 stamp due at the expiration of three years on Mr. Mushet's large batch of manganese patents; they were, consequently, allowed to lapse and become public property.

The author has, therefore, used without scruple, any of these numerous patents for manganese, without feeling an overwhelming sense of obligation to the patentee.

At the suggestion of the author, a works for the production of manganese alloys was erected by Mr. Henderson, at Glasgow, who now makes a very pure alloy of iron and manganese, containing from twenty-five to thirty per cent. of the latter metal, and possessing many advantages over spiegeleisen, which it will doubtless replace. Two bright rods of $1\frac{7}{8}$-inch in diameter will be found on the table. They were folded up cold under the hammer. This extremely tough metal is made by using Mr. Henderson's alloy in lieu of spiegeleisen, which is incapable of making steel of such a quality.

A Prussian gentleman, M. Preiger, has been also successful in manufacturing a new alloy, which he calls ferro-manganese, consisting of sixty to eighty per cent. of metallic manganese. It is extremely useful in making malleable iron by the Bessemer process in which spiegeliesen cannot be employed on account of the large proportion of carbon it contains.

It is gratifying to turn from a review of the troubles and impediments of the past, and briefly notice some of the more important applications of steel as a substitute for wrought iron.

In no case is this change of material more important than in the construction of ships, for in no instance are strength and lightness more essential.

The Bessemer cast steel made for ships' plates by the several eminent firms now engaged in that manufacture, is of an extremely tough and ductile quality, while it possesses a degree of strength about double that of the inferior kind of iron plates usually employed in shipbuilding, hence it is found that a much less weight of material may be employed, and at the same time, a greater degree of strength may be given to all parts subjected to heavy strains.

Most prominent among the builders of steel ships, is the firm of Jones, Quiggin, & Co., of Liverpool, who have now constructed no less than 31,510 tons of shipping wholly or partially built of steel. Of these, thirty-eight vessels are propelled by steam with an aggregate

of 5910 horse power; besides this the principal masts and spars of eighteen sailing ships have been made by them wholly of steel.

Vessels of a large size, constructed to class Aa twelve years at Lloyd's, weigh, when built of iron, about 12 cwt. per ton measurement; whereas, similar vessels built of steel weigh only about 7 cwt. per ton measurement; thus an iron ship, to take first class at Lloyd's for 1000 tons measurement, would weigh 250 tons more than a steel one of the same class. Such a vessel could, therefore, take 250 tons, or 25 per cent. more freight at the same cost, or could avail herself of the difference of immersion to leave or enter port when the tide would not permit an iron vessel to do so. As a steamer she would carry 250 more tons of coal, and thus be enabled to lengthen her voyage or take her coal for the return trip. The two steel paddle wheel steamers launched at Liverpool, by Messrs. Jones & Co., on the 13th ult., for Dublin and Liverpool service, will draw from 3 ft. to 4 ft. less water than iron steamers built on the same lines, and being thus enabled to leave port at all states of the tide, will not require a tidal train in connexion with them. If the employment of steel for the construction of merchant vessels is found to be so important, how much more is it for ships of war. Some of the larger class of armor-plated vessels require 6000 tons of iron for their construction, and an addition of 1800 tons in the shape of 4½-inch armor plates. Now, if the frames and inner skin of such a vessel were constructed of steel, it would be much stronger even if reduced to 4000 tons in weight; this would admit of 9-inch armor plates being used in lieu of 4½-inch, and would still leave the vessel 200 tons lighter than the present ones; and hence, as the resistance of the armor to impact is as the square of the thickness of the plate, we should have a vessel capable of resisting four times the force of those at present constructed, while it would be 200 tons less in weight.

These important facts have not escaped the attention of Mr. Reid, our present talented constructor of the navy, and we shall, doubtless, soon have substantial proof of what may be effected by the employment of steel in the construction of ships of war.

The application of steel for projectiles has now become a necessity since the introduction of armor plates. We have before us a 110 lb. shot, that has passed, with very slight injury, through a 5-inch armor plate, and also some specimens of bent angle iron, made of Bessemer iron, and rolled at the Millwall Iron works in London, and from the same works a portion of one of Hughes' patent hollow steel beams for supporting the armor plating in course of construction for the forts at Cronstadt; both these are interesting examples of what the rolling mills of the present day can effect, and of the facility with which cast malleable iron and cast steel admit of being worked into the most difficult forms.

There is no department in engineering in which the peculiar toughness of steel, and its strength and power of resisting wear and abrasion, are of such vital importance as in its application to railway purposes. This fact had long since impressed itself strongly on the mind of Mr. Ramsbottom, of the London and North Western Railway, who commenced experiments with this material in 1861; carefully, though

trustingly, he tried it step by step, not even at first venturing to employ it for passenger trains, but as proofs of its safety and economy crowded upon him, he carefully applied it to the most important parts of passenger engines, and even to the manufacture of the formidable engine cranks, (at that time entrusted only to the most eminent iron making firms of the kingdom.) These iron cranks are now being replaced by steel ones forged from a single mass. One of these steel cranks, manufactured at the new steel works at Crewe, has been obligingly lent by Mr. Ramsbottom as an illustration of the use of steel for this purpose; that gentleman has also taken out of use a plain steel axle that has run a distance of 112,516 miles and now exhibits very slight signs of wear.

The tires of wheels, on which so much of the public safety depends, were then tried, but the exact amount of difference between the endurançe of wrought iron and Bessemer steel for this purpose is not yet ascertained, as none of these steel tires are yet worn out; but enough has been shown to prove the advantage of entirely replacing iron by steel for this purpose.

In order to show how a steel tire will resist the most violent attempts to produce fracture, an example is given of a steel tire manufactured by Messrs. Bessemer & Co., of Sheffield; it was placed on edge under a six-ton steam hammer, and subjected to a series of powerful blows until it assumed its present form, that of a figure 8, a degree of violence immensely more than it could ever be subjected to in practice. These tires are made without weld or joint, by forging them from a square ingot, partly under the improved plan invented by Mr. Ramsbottom, and partly by an improved mode of flanging and rolling, invented by Mr. Allen, of the Bessemer Steel Works, Sheffield.

So important were found to be the advantages of employing cast steel as a substitute for wrought iron at the works of the London and North Western Railway Company, that the directors, acting under the advice of their able engineer, determined on building a large steel works at Crewe, which is now in active and successful operation. In the design and arrangement of their plant for working up the steel, several important improvements have been introduced by Mr. Ramsbottom, among others his duplex hammer, which strikes a bloom on both sides of the ingot at once, in a horizontal direction, and thus renders unnecessary the enormous foundations required for ordinary hammers. Here also he has put up his improved rolling mill for rolling blooms of large size, the enormous machine being reversed with the greatest rapidity and ease by the attendant, without any shock or concussion whatever.

While matters were thus steadily progressing in the engine department of the company, the engineer of the permanent way, Mr. Woodhouse, took in hand a thorough investigation of a no less important problem, viz: the substitution of cast steel for wrought iron railway bars. For this purpose some 500 tons of rails were made, and put down at various stations where the traffic was considerable, so as to arrive, at the earliest period, at a true comparison of the respective endurance of wrought

iron and cast steel rails. It will be unnecessary here to enter into the numerous details of the extensive series of experiments systematically carried out by Mr. Woodhouse; the trials made at Camden will suffice to show the extraordinary endurance of steel rails. It is supposed that there is not one spot on any railway in Europe where the amount of traffic equals that at the Chalkfarm bridge at Camden town. At this spot there is a narrow throat in the line, from which converges the whole system of rails employed at the London termini of this great railway. Here all passengers, goods, and coal traffic have to pass; here, also, the making up of trains and shunting of carriages is continually going on. At this particular spot two steel rails were fixed on May 2, 1862, on one side of the line, and two new iron rails were on the same day placed precisely opposite to them, so that no engine or carriage would pass over the iron rails without passing over the steel ones also. When the iron rails became too much worn to be any longer safe for the passage of trains, they were turned the other way upwards, and when the second side of the rails were worn as far as the safety of the traffic would allow, the worn out rail was replaced by a new iron one—the same process being repeated as often as was found necessary. Thus we find, at the date of the last report, on March 1, 1865, that seven rails had been entirely worn out on both faces. Since then another has been worn out up to July, making sixteen faces worn out, the seventeenth face being in use on August 22, when the steel rail that had been placed opposite to them was taken up in the presence of the writer, and, by the kind permission of Mr. Woodhouse, now lies on the table before the meeting. The first face of the rail only has been used, and this is now become much thinner than it was originally, but, in the opinion of the plate-layers, is still capable of wearing out another half dozen faces. Taking its resisting powers at three more faces only, it will show an endurance of twenty to one in favor of steel.

Mr. Woodhouse has ascertained, by careful and continued testing for twenty-four hours at a time, that an average of 8082 engines, tenders, or carriages, pass over the steel rails every twenty-four hours, equal to 16,164 wheels every day for 1207 days, making a total of 9,754,974 wheels passed over the rail. Subject to this excessive wear the rail appears to have been reduced $7\frac{1}{2}$ lbs per yard, hence for every grain in weight of steel lost by abrasion, no less than 371 wheels had to pass over it. Another steel rail, put down also in May, 1862, at a place much less subject to wear, has had four faces of iron rails worn out opposite to it, and still appears as if very little used; this rail is also placed on the table. An iron rail wears out by the giving way at various parts of the imperfectly welded mass, and not by the gradual loss of particles of metal, as in the case of the steel rail, which no amount of wear and tear seems capable of disjointing. It must be borne in mind that this enormous endurance of cast steel is not owing to its hardness and brittleness, as some have supposed, for, in fact, Bessemer steel possesses an extreme degree of toughness. There is before the meeting an example of this fact: one of the same quality of steel rails

having been attached at one end to the main driving shaft of a steam engine, so as to twist it while cold, into a long spiral, measuring nine feet in length at top and bottom, and only six feet if measured along the centre of the web. A single glance at this spiral rail will, it is presumed, dispel any idea of brittleness that may have been entertained.

In conclusion, it may be remarked that cast steel is now being used as a substitute for iron to a great and rapidly increasing extent.

The jury reports of the International Exhibition of 1851, show that the entire production of steel of all kinds in Sheffield was, at that period, 35,000 tons annually, of which about 18,000 tons were cast steel, equal to 346 tons per week; a few other small cast steel works in the country would probably bring up this quantity to 400 tons per week, as the entire production of cast steel in Great Britain. The jury report also states that an ingot of steel, called the "monster ingot," weighing 24 cwt., was exhibited by Messrs. Turton, and was supposed to be the largest mass of steel ever manufactured in England. Since that date a great change has been made, for the largest Bessemer apparatus at present erected at Sheffield, at the works of Messrs. John Brown & Co., is capable of producing with ease every four hours a mass of cast steel weighing 24 tons, being twenty times larger than the "monster ingot" of 1851.

There are now seventeen extensive Bessemer steel works in Great Britain. At the works of the Barrow Steel Company 1200 tons per week of finished steel can easily be turned out, and when their new converting house containing twelve more five-ton converters is completed, these magnificent works will be capable of producing weekly from 2000 to 2400 tons of cast steel. There are at present erected, and in course of erection, in England, no less than sixty converting vessels each capable of producing from three to ten tons at a single charge. When in regular operation, these vessels are capable of producing fully 6000 tons of steel weekly, or equal to fifteen times the entire production of cast steel in Great Britain before the introduction of the Bessemer process. The average selling price of this steel is at least £20 per ton below the average price at which cast steel was sold at the period mentioned. With the present means of production, therefore, a saving of no less than £6,240,000 per annum may be effected in Great Britain alone, even in this infant state of the Bessemer steel manufacture.

On Chemistry Applied to the Arts. By Dr. F. Crace Calvert, F.R.S., F.C.S.

From the London Chemical News, No. 248.

(Continued from page 341.)

Lecture V.

Milk, its composition, properties, falsification, and preservation. *Urine*, its uses. A few words on putrefaction.

Milk.—The composition of this important fluid varies, not only in different classes of animals, but also in different individuals of the same

class. Further, the composition of milk is modified by the influence of food, climate, degree of activity, and health. Notwithstanding these variations, an average can be arrived at by numerous analyses, and the following table will give a general idea of milk:

	Woman's.	Cow's.	Ass'.	Goat's.	Ewe's.
Dried caseine, .	15·2	44·8	18·2	40·2	45·8
Butter, . .	33·5	31·3	1·1	33·2	12·0
Sugar of milk, .	65·0	47·7	60·8	52·8	50·0
Salts, . .	4·5	6·0	3·4	5·8	6·8
Water, . .	881·8	870·2	916·5	868·0	885·4
	1000·0	1000·0	1000·0	1000·0	1000·0

The various substances comprised in milk may be classified under three heads: cream, curd or caseine, and whey.

Cream, according to Dr. Voelcker's* analysis, is composed of

Water, ...	61·67	64·80
Butter, ...	33·43	25·40
Caseine, ...	2·62	7·61
Sugar of milk, . .	1·56	
Mineral matters, .	0·72	2·19
	100·00	100·00

And may be considered as consisting of small, round, egg-shaped globules, composed of fatty matters, enclosed in a thin cell of caseine, which, being lighter than the fluid containing them, rise to the surface and constitute cream, and in proportion to the quantity of this removed from the milk, the latter becomes less opaque, and assumes a blue tinge. When exposed to the air for a short time in a dry place it loses water, becomes more compact, and constitutes what is called cream cheese. When churned, cream undergoes a complete change; the caseine cells are broken, and the fatty globules gradually adhere one to the other and form a solid fatty mass, called butter, and it is found, on an average, that 28 lbs. of milk will yield 1 lb. of butter. Fresh butter is composed of

Fatty matters, ...	Margarine, Oleine, Caproine, Caprine, Butyrene, Caproleine, ...	77·5
Caseine, ...		1·6
Whey, ...		20·9
		100·0

* For further particulars on this subject, the reader is referred to Dr. Voelcker's paper, published in the *Journal of the Royal Agricultural Society of England*, volume xxiv.

But, as butter rapidly becomes rancid, it is necessary to adopt means to prevent this as much as possible, and the following are the usual methods, viz: working the butter well with water, and then adding 3 or 4 per cent. of common salt, or melting the butter at a temperature below 212°; but the following method, employed by M. Bréon, appears to give general satisfaction: It consists in adding to the butter water containing 0.003 of acetic or tartaric acid, and carefully closing the vessels containing it. The rancidity of butter is due to a fermentation generated by the caseine existing in it, which unfolds the fatty matters into their respective acids and glycerine, and as the volatile acids, butyric, caproic, &c., have a most disagreeable taste and odor, it is these which impart to butter the rank taste. Allow me to add, *en passant*, that whilst butyric acid possesses a repulsive smell, its ether has a most fragrant odor, viz: that of pineapple, for which it is sold in commerce.

Curd of Milk, or Caseine, has, according to Dr. Voelcker, the following composition:

Carbon,	53·57
Hydrogen,	7·14
Nitrogen,	15·41
Oxygen,	22·03
Sulphur,	1·11
Phosphorus,	0·74
	100·00

And is easily recognizable by its white flocculent appearance. It is insipid and inodorous, like albumen, from which it differs in its insolubility in water, though it is dissolved by a weak solution of alkali or acid. But what chiefly distinguishes caseine is, that it is not coagulated on boiling, and that rennet precipitates it from its solutions. Dr. Voelcker has proved, however, in his researches on cheese, that the commonly received opinion that rennet coagulates milk by decomposing the lactine into lactic acid is incorrect, for he has coagulated milk while in an alkaline condition, and it is owing to the difference in the action of rennet on albumen and caseine that chemists have been able to detect the presence of $\frac{1}{2}$ to $\frac{3}{4}$ per cent. of albumen in milk. This important organic substance not only exists in milk, but is also found in small quantities in the blood of some animals, such as the ox, and in a large class of plants, but more especially in the leguminous tribe, such as peas, beans, &c. Caseine is the basis of all cheeses, and when these are made with milk from which the cream has been previously taken, the cheese is dry, but when part of the cream has been left, the cheese is rich in fatty matters as well as in caseine; and I may add that the peculiar flavors characterising different cheeses are caused by modifying the conditions of the fermentations which the organic matters undergo. The following researches made by M. Blondeau illustrate this point, as well as the modifications which cryptogamic life, under peculiar circumstances, may effect in the composition of organic substances, and his interesting results were obtained in studying the

conversion of curd into the well known cheese of Roquefort. He placed in a cellar some curd of the following composition:

Caseine,	85·43
Fatty matters,	1·85
Lactic acid,	0·88
Water,	11·84
	100·00

To which he added a small quantity of salt. After a month, and again after two months, he analysed portions of the same, with the following results:

	After one month.	After two months.
Caseine,	61·33	43·28
Fatty matters.	16·12	32·31
Chloride of sodium,	4·40	4·45
Water,	18·15	19·16
Butyric acid,	. .	0·67
	100·00	99·87

The above figures show a most extraordinary change in the caseine or curd, for we observed that the proportion of caseine gradually decreases, and is replaced by fatty matters. Considering the circumstances under which this phenomenon has occurred, there can be no doubt that this curious conversion of an animal matter into a fatty one is due to a cryptogamic vegetation or ferment; and if the Roquefort cheese be exposed to the air under a bell jar for twelve months, the decomposition becomes still more complete; for it is no longer the caseine which undergoes a transformation, but the oleine of the fatty matters. The following analyses clearly illustrate this curious action. Composition of the cheese after two and twelve months:

	After two months.	After twelve months.
Caseine,	43·28	40·23
Margarine,	18·30	16·85
Oleine,	14·00	1·48
Butyric acid,	0·67	. .
Common salt,	4·45	4·45
Water,	19·30	15·16
Butyrate of ammonia,	. .	5·62
Caproate of "	. .	7·31
Carprylate of "	. .	4·18
Caprate of "	. .	4·21
	100·00	99·49

The substances to which cheeses owe their peculiar flavor are ammoniacal salts, chiefly composed of various organic acids, such as acetic, butyric, capric, caproic, and caproleic. I cannot better conclude my remarks on cheese than by extracting from Dr. Voelcker's interesting papers a few of his analyses of different kinds of cheese:

	Cheshire.	Stilton.	Old Cheddar.	Double Glo'ster.	Single Glo'ster.	American.
Water, . .	32·59	20·27	30·32	32·44	28·10	27·29
Butter, . .	32·51	43·98	35·53	30·17	33·68	35·41
†Caseine, . .	26·06	33·55	28·18	31·75	30·31	25·87
Sugar of milk, Lactic acid,	4·53		1·66	1·22	3·72	6·21
†Mineral matter,	4·31	2·20	4·31	4·42	4·19	5·22
	100·00	100·00	100·00	100·00	100·00	100·00
†Nitrogen, .	4·17	3·89	4·51	5·12	4·85	4·14
†Common salt, .	1·59	0·29	1·55	1·41	1·12	1·97

The principal applications of caseine in arts and manufactures is that first introduced by Mr. R. T. Pattison, who used it, under the name of lactarine, for fixing pigments in calico printing. His process consists in drying the washed curds of milk, which he sells to the calico printer, who mixes it with a solution of ammonia or weak alkali, which swells it out and renders it soluble in water. To a solution of this substance, of proper consistency, he adds one of the tar colors, prints it, submits the goods to the action of steam, which drives off the ammonia, leaving fixed on the fabric the caseine and color. In consequence of the insoluble compound which caseine forms with lime, it has often been used as a substitute for glue or linseed oil in house painting, and it may be useful to some of my audience to know that when caseine is dissolved in a concentrated solution of borax, an adhesive fluid is formed, which is capable, in many cases, of serving the purposes of glue or starch. Mr. Wagner has made another useful application of caseine, mixing it with six parts of calcined magnesia, and one part of oxide of zinc, and a sufficient quantity of water to make a pasty mass, which he leaves to solidify, and when dry it is extremely hard, susceptible of receiving a high polish, and is sold as a substitute for meerschaum.

Whey.—According to Dr. Voelcker, the composition of whey is as follows:

Water, ...	89·65
Butter, ...	0·79
Caseine, ...	3·01
Sugar of milk, ...	5·72
Mineral matters, ...	0·83
	100·00

When whey is concentrated to the state of syrup, and kept in a cold place, it gradually deposits fine, well defined crystals, which, on further purification and re-crystallization, yield white quadrangular prisms of a substance called lactine, or sugar of milk, which is highly interesting. It is remarkable that, while sugar of milk has only been known in Europe for a comparatively short period, where homœopathists are its principal

employers, in India lacthine has been known for a great number of years. Let us now study some of the chemical facts connected with the history of sugar of milk. Thus, cane sugar, when acted upon by nitric acid, gives oxalic acid, whilst lactine gives mucic acid. Cane sugar, when unfolded under the influence of a ferment, gives alcohol and carbonic acid; lactine yields lactic acid. As the latter transformation is most important, in a physiological and chemical point of view, allow me to dwell upon it for a few minutes. The substance which possesses the property of most readily converting lactine into lactic acid is caseine after it has undergone some peculiar modification, which renders it a ferment. Thus, when milk leaves the cow it is alkaline, but when exposed to the air it rapidly becomes acid, and this is due to the conversion of lactine into lactic acid, a change most interesting as a chemical fact, since both lactine and lactic acid have the same composition, the only difference being that two equivalents of oxygen and two of hydrogen cease to exist as such in the acid, but may be considered as combined in the form of water with the remaining elements:

$$\text{Lactine } C_{12}H_{12}O_{12} = 2 \text{ Lactic acid } (C_6H_5O_5HO.)$$

M. Pasteur has shown that this lactic fermentation is not merely confined to milk, but that it is a peculiar fermentation, differing from the previous one, which frequently occurs during the decomposition of organic matters, and is due to a distinct ferment of its own; and his researches on lactic fermentation have explained the fact, observed by M. Pelouze some years since, that when a vegetable substance, such as sugar or starch, was put in contact with chalk or other alkali and an animal substance, lactic fermentation ensued, but, until the researches of M. Pasteur, we did not know why sugar and starch in these circumstances should give lactic acid instead of alcohol and carbonic acid, which would be the result of a fermentation produced by yeast. Lactic acid is a most interesting substance to the physiologist, for it is found in larg equantities, free or combined with lime, in gastric juice in the muscular part of animals, or with soda in blood, and its production is easily accounted for when we remember that it can be produced from the starch and sugar existing in our food. When lactic acid is purified by various chemical means, and separated from the fluid in which it is combined, it presents itself as a syrupy fluid of an intensely acid reaction, which, when submitted to the action of heat, first loses its one equivalent of water, and becomes anhydrous lactic acid, and on a further application of heat loses still one equivalent of water, and is transformed into a neutral substance called lactide. This acid in a free state has not yet received any important application in art and manufactures, but I have little doubt that it will some day be largely employed, for we have noticed in a former lecture its advantageous use when produced from rye and other amylaceous substances in removing the lime from various skins intended to be tanned or prepared as there described, and Mr. E. Hunt has used it in the form of sour milk for the conversion of salt into dextrine, (see *Journal of the Society of Arts*, December 23, 1859.) I wish now to say a few words on the mineral

substances existing in whey, and which play a most important part in milk as a nutritious substance. We are all of us too apt to overlook the importance of the mineral elements in food, and to consider as essential the organic matters only. In milk, however, its alkaline salts, and especially the phosphate of lime, are as essential (as food) as caseine or fatty matters, for if an infant requires the lactine to maintain respiration and the heat of the body, the caseine to contribute to the formation of blood, the phosphate of lime is equally essential to the production of bone; permit me here to state that the practice adopted by some mothers of feeding infants upon amylaceous substances, such as arrowroot, sago, tapioca, &c., in place of milk, is most pernicious, for these contain neither flesh nor bone forming element, and milk is the only proper food for infants.

Having now examined the general properties of some of the most important constituents of milk, let us say a few words on that fluid in its integrity. We all know how rapidly milk becomes sour, especially at a temperature of 70° to 90°, and this is owing, as already explained, to the formation of lactic acid. The best way to preserve milk sweet for domestic purposes is to add to it every day a few grains of carbonate of soda per pint to keep the milk alkaline. The possibility of preserving milk for a lengthened period has repeatedly occupied the attention of scientific men, as a most important problem to solve for the benefit of persons undergoing long sea voyages, but, up to a recent date, with very imperfect success. One of the best plans proposed is to add to milk 7 or 8 per cent of sugar, and evaporate the whole, agitating all the time to prevent the formation of the skin, and, when reduced to one fifth its bulk, to introduce it into tin cans, which, after being subjected for half an hour to a temperature of 220°, are hermetically sealed. In 1855, l'Abbé Moigno drew the attention of the members of the British Association, at Glasgow, to milk which he stated contained nothing injurious, and which would keep for a long period. This statement has proved correct, for I have here some milk which has been in the hands of the Secretary of this Society since that period, and which, on being opened to-day, was found perfectly sweet. But if l'Abbé Moigno's process had remained a secret, M. Pasteur has succeeded in affecting the same end, and probably by the same method. Thus, he has found that if milk be heated to 212°, it will only remain sweet for a few days, if heated to 220°, it will remain sweet for several weeks, but if to 250°, (under pressure, of course,) the milk will keep for any length of time. This, according to M. Pasteur, is owing to the spores or eggs which generate lactic fermentation being destroyed by the high temperature, and thus the possibility of fermentation is put an end to. The adulteration of milk by various substances stated to have been discovered therein, has, I think, been greatly over estimated, as I have never found any of them in the samples of milk which I have analysed. In fact, the most easy and cheapest of all is the addition of water. It is comparatively to ascertain if milk has been tampered with, but, without entering into details of the methods necessary to estimate the exact extent of adulteration, I may mention the following plan: If a glass

tube, divided into 100 equal parts, is filled with milk and left standing for twenty-four hours, the cream will rise to the upper part of the tube, and, if the milk is genuine, will occupy from 11 to 13 divisions. Another practical method is to add to the milk a little caustic soda, and agitate the whole with a little ether and alcohol, which dissolves the fatty matters; this etherial solution is removed from the milk and evaporated, when the fatty matters remain, and experience has shown that 1000 parts of good milk will yield 37 parts of fatty matters. Any milk leaving no more than 27 must have been tampered with. Dr. Voelcker suggests the employment of a hydrometer as a means of ascertaining the quality of milk, as the specific gravity of that fluid is an excellent test. From a great number of experiments he has ascertained that good new milk has a specific gravity of 1·030, whilst if good milk is adulterated with 20 per cent. of water, its specific gravity will fall to 1·025.

Urine is a fluid secreted by the kidneys, which organs separate from the blood as it circulates through them any excess of water it may contain, as well as many organic substances which have fulfilled their vital function in the animal economy, and which require to be removed from the system. The composition of urine varies greatly in different individuals, and in the same individual at different times, and is influenced by diet, exercise, state of health, &c., as shown by Dr. Bence Jones and Dr. Edward Smith; but without detailing these variations, which would occupy far more than the limits of a lecture would permit, allow me to call your attention to the following table, showing the composition of human and herbivorous animal's urine:

HUMAN.

Water,	933·000
Urea,	30·100
Lactic acid, Lactate of ammonia, Extractive matter, Kreatine, Kreatinine, Hippuric acid, Indican, Colloid acid,	17·140
Uric acid,	1·000
Mucus,	0·320
Mineral salts,	18·440
	1000·000

HORSES.

Water,	910·76
Urea,	31·00
Hippurate of potash,	4·74
Lactate of do.	11·28
Do. of soda,	8·81
Bicarbonate of potash,	15·50
Carbonate of lime,	10·82
Carbonate of magnesia,	4·16
Other salts,	2·93
	1000·00

The substances in human urine which call for special notice are urea and uric acid; in herbivorous animals, hippuric acid; and in birds, uric acid.

Urea is a substance crystallising in various derivative forms belonging to the prismatic system; it is very soluble in water and alcohol, and gives beautiful and well defined salts with nitric and oxalic acids. Urea, under the influence of a mucous substance secreted at the same time, and which is easily modified into a ferment, is rapidly converted, by the fixation of two atoms of water into carbonate of ammonia, as seen by this formula:

Urea, ...	$C_2\ O_2\ N_2\ H_4$
Water, ...	$O_2\ H_2$
Carbonate of ammonia, . . .	$C_2\ O_4\ N_2\ H_6$

This will explain the strong ammoniacal odor arising from urine after being kept for a short time; and as it may be most important for medical men to be able to preserve urine in its normal condition for several days, I observed a few years since a most effectual method of preserving it, which is merely the addition of a few drops of carbolic acid immediately after the production of the urine. Urea is peculiarly interesting to chemists, as it was the first organic substance which they succeeded in producing artificially from mineral compounds. This interesting discovery was made by Wöhler, in 1820, in acting upon cyanate of silver by hydrochlorate of ammonia. Since then, Baron Liebig has devised a more simple process, which consists in decomposing cyanate of potash by sulphate of ammonia, which gives rise to sulphate of potash and cyanate of ammonia, or urea. The average quantity of urea rejected daily by an adult man is about an ounce, or $2\frac{1}{2}$ per cent. of the fluid itself. Although human urine does not contain more than one per cent. of uric acid, and this generally combined with soda, still, I deem it my duty to say a few words respecting it, for it is often the source of gravel and calculus, owing to various influences which make the urine strongly acid before its rejection, whereby the soda is neutralized, the uric acid liberated, and this being nearly insoluble, separates, and has a tendency to form gravel or calculus. In fact, the deposit which occurs in this fluid is generally represented by uric acid, phosphate of lime, and magnesia, mucus, and coloring matter. It may be here stated that calculi were formerly held in great estimation, especially those formed in the intestine, and called bezoards, and this was the case in Eastern countries until very recently. Thus, it is related that a Shah of Persia sent to Napoleon I, among other valuable presents, three bezoards, which were considered to be of great antiquity and capable of curing all diseases. The urine of birds and reptiles being almost entirely composed of urate of lime, explains why their refuse is of such value as a manure, which arises from its transformation into carbonate of ammonia. When large masses of this refuse undergo a slow and gradual decomposition, as in the dry climate of the Pacific Islands, on the coasts of Peru and Chili, it constitutes guano. It may be interesting to know that in 1835–36–37, a most

beautiful color was prepared from the uric acid contained in guano, and used largely by calico printers and silk dyers under the name of Roman purple, or murexide.*

Before leaving the study of this important animal secretion, let me say a few words on the urine of herbivorous animals. It is generally alkaline, and contains, besides an aromatic principle, an acid discovered by Liebig, and called hippuric acid, together with urea and uric acid, also found in human urine. Hippuric acid is easily obtained in the well defined crystals, by rapidly evaporating the fluid containing it. This acid does not exist in the food of the animal; but benzoic acid, or its homologues, are found there, and, during the phenomena of digestion, the nitrogenated principles produced by the wear and tear of life fix themselves on benzoic acid, and convert it into hippuric, as seen by this formula:

$$\underset{\text{Benzoic acid.}}{C_{14}H_5O_3+HO} \quad . \quad . \quad \underset{\text{Hippuric acid.}}{C_{18}H_8O_5N_2+HO.}$$

A further proof of the correctness of this view is that when hippuric acid is treated with strong acids or alkali, it transforms itself into benzoic acid, which can be easily extracted.

(To be continued.)

On the Action of Silicate and Carbonate of Soda in Cotton Fibre.

By F. Grace Calvert, F.R.S., F.C.S.

From the London Journal of the Chemical Society, March, 1865.

I have lately been engaged in investigating a case of injury to goods, which I hope will prove interesting to chemists and manufacturers, from the novelty of the ascertained chemical facts to which the injury is traceable.

A large quantity of blue-tipped indigo cotton goods, with white reserves, were shipped two or three years ago to South Africa, and when opened some time after their arrival, were found so unsound as to be quite unsaleable, the cotton fibres being so much injured as to give way upon the slightest strain. The goods were, therefore, returned to this country, and placed in my hands to investigate the cause which had produced this damage.

As a large number of bales were returned without having been opened abroad, an excellent opportunity offered itself for selecting a well defined series of pieces for experiments, and also for judging of the effects of packing on goods generally, when exposed for a long period to the hot and moist atmosphere of tropical climates.

First, on opening the bales, I observed that the boiled oil cloth which had been employed to protect the goods from external damp, yielded, when subjected to a very slight strain, proving that the texture of the cotton fibre had been injured by the oxidation it had undergone, in consequence of its having been saturated with boiled oil.

Secondly, on examining the goods forming the bales, it was found, in every instance, that the outer folds, including the second, and some-

* See, for further details, my lecture at this Society, February 5, 1862.

times the third, were stained and dirty, but this did not extend deeper, the inner folds being perfectly free from stain or mildew. These facts show the importance of returning to this country (where claims are intended to be made upon the manufacturers or packers) entire and unopened bales of goods, instead of a few sample pieces, which cannot show the state of the bales, and enable the examiner to speak with certainty as to the cause of injury.

I also ascertained that the rottenness of the fabric could not have been caused by their having been packed in a damp condition, for the hygrometric moisture of a piece in the centre did not exceed 8·5 per cent. Further, the goods were carefully examined to ascertain if any mildew could be discovered, which would have occurred if the goods had been packed in a damp state, and which would have certainly developed itself more fully in the interior of the bales than nearer the outside, if damp packing had been the cause. What completely removed from my mind all doubt as to the cause, was that, on carefully examining the pieces composing the bales, I found among the injured pieces, some which were quite sound, and on submitting these pieces to analysis, comparatively with those which were injured, the following results were obtained:

The sound pieces left only from 0·55 to 0·65 of ash, whilst the injured pieces left 8·29 and 8·59 of ash, the composition of which was as follows:

	No. 1.	No. 2.
Insoluble Silica,	2·94	3·81
Silica combined with soda,	2·35	2·53
Soda,	1·77	1·60
Other salts, Sulphate of soda, Chloride of sodium, Sulphate of lead, &c.,	1·23	0·65
	8·29	8·59

These analyses show that the pieces had been finished with silicate of soda, which had undergone a partial decomposition; while the pieces which left only a few thousandths of ash were found, on further examination, to have been finished in the ordinary way, viz: with amylaeous substances. This induced me to examine more minutely the goods, to ascertain whether it was to the silicate of soda, or to the carbonate of soda, arising out of its decomposition, that the injury sustained was due; and I was further prompted to carry on this investigation from the fact that at the present time, the tendency amongst manufacturers is to weight their goods. It is well known that the risk of mildew is considerably increased in proportion to the weight of size; consequently there is a great inducement to use mineral, in preference to vegetable substances for that purpose. I therefore trust that the results now published will warn manufacturers of the risk they run in using mineral size, without great care and experience, whilst on this point I may be permitted to give here an insight into the nature of the size often used in Lancashire for sizing the warps of grey calicos, and, therefore, I give a few of the results obtained at my laboratory.

Analysis of Various Cloths.

No. 1.

Mineral matter, principally clay and sulphate of magnesia,	5·2
Water in excess,	2·8
Fermented flour,	10·0
Hygrometric moisture,	8·0
Fibre,	74·0
	100·0

No. 2.

Mineral matter, principally sulphates of baryta and magnesia,	4·5
Water in access,	2·1
Fermented flour,	11·3
Hygrometric moisture,	8·0
Fibre,	74·1
	100·0

No. 3.

Mineral matter, principally sulphate of soda and clay,	4·8
Flour,	10·0
Water in excess,	4·5
Hygrometric moisture,	8·0
Fibre,	72·7
	100·0

No. 4.

Mineral matter,	1·24
Water in excess,	1·74
Fermented flour,	13·02
Hygrometric moisture,	8·00
Fibre,	76·00
	100·00

The above data show that warps are sized with sour flour (viz: flour which has been allowed to ferment for several days or weeks) and various mineral matters, to the amount, irrespective of moisture, of about 15 per cent. There can be no doubt that goods thus sized are extremely liable to mildew, owing, on the one hand, to the use of fermented flour, or organic matter in a state of decay, and on the other, to the use of clay, which tenaciously retains moisture, which facilitates cryptogamic vegetation when the goods are packed. I may state, *en passant*, that sulphate of magnesia, sulphate of lime, sulphate of baryta, sulphate of soda, and the chlorides of sodium and magnesium are often used, with or without clay, as weighting materials.

On examining the comparative strength of various pieces composing a bale, I observed that the outside folds of the pieces which formed the external parts of the bale (above alluded to as dirty and stained) were comparatively strong when tested against the folds of the same piece which were towards the interior of the bale. I therefore took the same weight of cloth from both classes of folds and submitted them to analysis, with the following results:

	Interior of bale.	Exterior of bale.
Insoluble silica, . . .	4·81	7·08
Silica combined with soda, .	2·53	0·20
Soda, ...	1·60	0·47
Other salts, . . .	0·65	0·55
	8·59	8·30

On examining and comparing these figures, it is at once seen that the stained fold shows a large increase in the amount of insoluble silica, and a corresponding decrease in the amount of silica combined with soda; but, notwithstanding this, the total amount of silica is nearly the same in both classes of cloth. Further, that there is a total disappearance in the stained fold of 1·13 per cent., or more than two-thirds of the total amount of soda. From the results it would appear that the silicate of soda, when first applied to the goods, contained the whole of its silica in combination with the soda, and that, under the influence of the carbonic acid of the atmosphere, the silicate of soda has been decomposed into insoluble silica and carbonate of soda, thereby giving rise to great increase in bulk; whilst in the goods which were protected from an excess of moisture—as towards the interior of the bales, —and also from the action of carbonic acid, there is only a partial decomposition of the silicate of soda. Mr. Walter Crum has kindly suggested, and I believe the view to be correct, that the cotton fibre has, by its organic nature, a cohesive attraction for silica, which enhances the decomposition of the silicate of soda employed to finish and weight the goods.

From these facts we may assume that there were two destructive influences brought to bear upon the cotton fibre: 1st, that of the increase of bulk resulting from the decomposition of the silicate of soda, giving rise to the formation of free silica and carbonate of soda, which exercised a distending and disintegrating action upon the cellular tissue of the cotton fibre, causing it to burst, and necessarily weakening its tensile strength; 2d, the direct and destructive action of the free carbonate of soda upon the fibre. The latter appears to be the principal cause of injury, for in the external folds we have a more complete decomposition of the silicate, as shown in the above figures, by the increase in the amount of insoluble silica, and at the same time a decrease of the soda, amounting, as previously stated, to more than two-thirds of the total weight.

We shall now trace more in detail this interesting decomposition of silicate of soda, and endeavor to show what had become of the soda which had disappeared. To attain this object, a complete series of specimens were obtained from an entire bale, viz: 1, a piece which formed the outside and was stained; 2, some of the paper employed in wrapping the goods, which was in immediate contact with the stained cloth; and 3, some of the flax wrapping placed next to the paper and between the latter and the oil-cloth covering above alluded to. The following are the results yielded by analysis:

	Pieces of Goods.		Paper Wrapping.		Flax Wrapping.	
	No. 1. inside fold.	No. 2. outside fold.	No. 3. in contact.	No. 4. not in contact.	No. 5. in contact.	No. 6. not in contact.
Insoluble silica, . . .	4·05	5·65	0·02	0·03	0·04	0·01
Silica combined with soda, . . .	2·21	0·38	0·09	0·02	0·08	8·03
Soda, ...	1·76	0·25	0·85	0·01	0·29	0·02
Other substances, .	1·96	1·91	15·15	15·28	1·19	1·25
Total ash, ...	9·98	8·19	16·11	15·34	1·58	1·31

In examining these results we have again a most striking and marked difference in the amount of insoluble silica and soluble silicate of soda in the two different parts of the same cloth; and, further, where the carbonate of soda has been removed, the folds of the cloth remain comparatively sound. As to the paper wrapping, it is evident that the paper in contact with the goods has absorbed a great part of the soda which was previously combined with the silica, and that the soda is partly in the state of carbonate, and partly in combination with some of the organic matter of the brown paper; for, when some of the paper was treated with water, it yielded a yellowish brown substance which colored the liquid, whilst the part of the same paper which had not been in contact with the goods did not discolor the water in any marked degree. Further, the aqueous solution was neutral and not alkaline, as in the previous case. As to the flax wrapping, the same difference as noted in the paper was observed, viz: that the part of the wrapping in contact with the stained paper and the stained fabric contained carbonate of soda, whilst that which was in contact with the clean paper contained only a trace. In looking over the bales, a piece of cloth was found which had been finished with silicate of soda, and was partly overlapped by another piece, showing one-half of its exterior fold stained and comparatively sound, whilst that half of the fold which was prevented from forming the exterior of the bale by being overlapped by the previous one, was quite tender and rotten, though it showed no signs of any stains or mildew. I also examined a sound piece which had laid in contact with an injured one, and found that in those folds which had been in contact there was in the injured piece less soluble silicate, and in the folds of the sound piece a considerable quantity of carbonate of soda, the presence of which could not be found in the folds forming the centre of it.

Having observed that the reserved white patterns of the blue-dipped indigo cloth were a great deal more tender than the blue portions of the same piece, I carefully cut out a portion of the white parts and submitted them, with the blue parts, to analysis, with the following results:

	White.	Blue.
Insoluble silica, . . .	5·48	3·17
Silica combined with soda, . .	0·18	2·10
Soda, ...	0·78	1·43
Other salts, . . .	1·08	0·67
Total, . . .	7·52	7·37

These figures illustrate the fact that the decomposition of the silicate of soda has been carried on to a much greater extent in the white parts than in the blue; and I am led to believe that the cause of the increased rottenness in the white is due to the printer having used a resist-paste too acid, and having found that the whites were slightly tendered, he endeavored to check the further action of the acid on the cotton fibre (which, as chemists well know, continues until the cotton fibre is completely destroyed) by the employment of a strong solution of silicate of soda, which, being an alkaline salt, was well adapted to neutralize any acid in the cloth and arrest its action. And, as previously, only weak solutions of silicate of soda had been employed for this purpose, the printer of these goods could not have foreseen that the use of a more concentrated solution would result in such serious consequences. The above figures also prove another interesting fact, viz: that the white parts of the cloth contain a much larger proportion of silicate of soda than the blues, thus proving that the dyed indigo fibres, being partially filled with this resinous dyeing material, were not in a condition to absorb so largely the silicate of soda.

Messrs. H. Caro & Dancer, who were also employed to investigate this matter, entertain a different opinion as to the cause of the white parts being more injured than the blues. These gentlemen are led to believe, from their results, that the reason why the whites are more injured than the blues is, that a slow chemical action has ensued between the sulphate of lead remaining from the reserve paste and the silicate of soda, and that a silicate of lead has been formed, and, as this salt occupies a larger bulk than the sulphate of lead previously existing in the fibre, the production of it inside the cellular tissue of the fibre has been the cause of the increased tenderness of the whites. But as these gentlemen are engaged in investigating the question more fully, I shall leave to them the pleasure of publishing their results.

Lastly, I deemed it my duty to make some direct experiments on the action of silicate of soda on cotton fibre. I therefore took some white cotton and dyed a portion of it with indigo. This blue dyed cloth, with a part of the white one, were dipped in a moderately strong solution of silicate of soda, then dried, and a portion of them introduced into a bottle, at the bottom of which a little of water had been placed, and to help the action of the carbonic acid of the *atmosphere*, a slow current of carbonic acid was then passed through the bottles containing the cloths. After three months' time the warps of these samples were tested, and their comparative breaking weights were found to be as follows:

	On an average of 10 essays.
The warps of the unsilicated cloth dyed blue, . .	334
The same silicated, ...	299 284 289

The results leave no doubt that the warps, even during the short period of three months, had been considerably injured by contact with

silicate of soda. In conclusion, I beg to add that I am aware that silicate of soda has been used for finishing colored goods, but when employed it has been in a very dilute state, and therefore its destructive action has not been sufficiently marked to draw the attention of calico printers.

Pharaoh's Serpents' Eggs.—The Preparation of Sulphocyanide of Ammonium.

From the London British Journal of Photography, No. 284.

By referring to the letter of our foreign correspondent, some notice of these curious chemical toys will be found. Mr. C. H. Wood gives the following process for preparing the white powder, and, as his remarks embrace the preparation of sulphocyanide of ammonium, which is used by several persons as a fixing agent for positive prints, we feel that they will be all the more welcome. Describing the toy, Mr. Wood says:

"It consists of a little cone of tin foil, containing a white powder, about an inch in height, and resembling a pastile. This cone is to be lighted at its apex, when there immediately begins issuing from it a thick, serpent-like coil, which continues twisting and increasing in length to an almost incredible extent. The quantity of matter thus produced is truly marvellous, especially as the coil which so exudes is solid and may be handled, although, of course, it is extremely light and somewhat fragile.

"Having a little of the white powder, with which the cones are filled, placed at my disposal by a friend, I submitted it to analysis, and found it to consist of sulphocyanide of mercury. This salt, when heated to a temperature below redness, undergoes decomposition, swelling or growing in size in a most remarkable manner, and producing a mixture of *mellon* (a compound of carbon and nitrogen) with a little sulphide of mercury. The resulting mass often assumes a most fantastic shape, and is sufficiently coherent to retain its form. It presents a yellow color on the exterior, but is black within. The "serpent" shape, of course, results from the salt being burnt in a cone of tin foil.

"Both the mercurous and mercuric sulphocyanides decompose in the same manner, but the mercuric salt, containing more sulphocyanogen, seems capable of furnishing a larger quantity of mellon, and is the one used in the French serpents. A solution of pernitrate of mercury is readily precipitated by sulphocyanide of ammonium, and the mercuric sulphocyanide may be easily so prepared. It is best to use the mercurial solution as strong as possible, and to *keep it in excess* throughout the precipitation. Solution of perchloride of mercury is not so easily precipitated as the pernitrate, probably owing to the solubility of the mercuric sulphocyanide in the chlorides.

"Perhaps I may be excused for adding that sulphocyanide of ammonium, suitable for the above purpose, may be very easily and economically prepared as follows: One volume of bisulphide of carbon,

four volumes of liq. of ammon. fort., and four volumes of methylated spirit are put into a large bottle, and the mixture frequently shaken. In the course of one or two hours the sulphide of carbon will have entirely dissolved in the ammoniacal liquid, forming a deep red solution. When this result is attained, the liquid is boiled until the red color disappears and is replaced by a light yellow. The solution is then evaporated at a *very gentle heat* (about 80° or 90° F.) until it crystallises, or just to dryness. The product is sulphocyanide of ammonium sufficiently pure for the above purpose. One recrystallization in alcohol will render it quite white.

"One ounce of bisulphide of carbon yields, by this process, exactly one ounce of sulphocyanide of ammonium."

Substitute for Blasting Powder.

From the London Artizan, May, 1865.

At Stockholm, several experiments have been made with nitro-glycerine, in order to test its application as a substitute for blasting powder in mining operations. They were considered very successful, the new compound being found to be superior in its effects to the ancient method, and the price considerably less. Among other trials, a hole bored near the summit of a rock to a depth of 23 feet, was charged with $5\frac{1}{2}$ lbs. of nitro-glycerine. Five minutes after the fuze had been lighted a dull report was heard, and enormous blocks were detached from the rock. Several other mines were fired with blasting powder, but their effects were inferior to those of the nitro-glycerine.

Anti-Fouling Composition.

From the London Artizan, May, 1865.

The *Orontes* screw iron troopship, and the *Hector*, screw iron frigate, have both been docked at Portsmouth to examine, and report upon, and replenish the preservative and anti-fouling compositions with which their hulls below the water line were coated when they were last placed in dock. The bottom of the *Orontes* was found to be free of any important accumulation of weeds, but, under the counter of her stern, and in the run of her lines to her screw aperture, she is thickly encrusted with barnacles, and the bottom is dotted all over with patches of rust, the rivet heads in many places showing evident signs of being affected by the copper contained in the "anti-fouling" composition. As a "preservative" to the ship's bottom, the composition appears to have utterly failed. As an "anti-fouling" preparation, the result is rather more favorable, but this slight advantage appears to have been more than counterbalanced by the failure in "protective" qualities to the iron of the ship's bottom. The compositions used on the *Orontes* were the Admiralty's, or Hay's improved. The compositions were payed on the *Orontes*' bottom when she was in dock in August last.

Preservation of Gun Cotton.

M. M. Blondeau makes the following communication to the French Academy of Sciences: Taken gun cotton of good quality, and expose it for about four hours to the action of the vapor of ammonia. The cotton will soon assume a yellow tint, indicating its combination with the ammonia, and after being dried it furnishes a powder which, besides being unalterable at ordinary temperatures and even undecomposable at 212°, (Fahr.,) possesses an explosive force greater than that of ordinary gun cotton.

Results of the Experiments on the Carburation of Coal Gas. By H. Letheby, M. B., M. A., Ph. D., &c., Medical Officer of Health and Gas Analyst for the City of London.

From the London Chemical News, No. 276.

The experiments made during the last two years on the carburation of gas at the street lamps, have developed a number of facts that should be placed on record, for these facts are not merely of scientific interest, they are also of practical value.

A common notion prevails that the use of the carburettors in the public lamps has not been successful. I have, therefore, made it my business to ascertain whether this notion is founded on fact, and if so, whether the failure is due to an imperfection in the principle of the process, or to the manner in which it has been applied.

On the first of these heads it is necessary only to say that, while, on the one hand, it cannot be denied that the use of the carburettors has not given public satisfaction, so, on the other, it must be admitted that, although the process has not been fairly applied, its want of success is by no means so great as is generally supposed.

The principle involved in the process is, beyond all question, a correct principle, in so far as it relates in its application to the very inferior gas of London; but the success of the process is dependent on certain conditions which have not always been fulfilled. It has been ascertained, in fact, that the results of the process are affected by a great number of circumstances, many of which have been either disregarded, or have been placed beyond our control. These circumstances are—the quality of the naphtha, the time of the experiment, the temperature of the apparatus, the form of the carburettor, the quality of the gas, and the rate at which it traverses the instrument. All these circumstances have received attention, and the following are the results of it:

As regards the quality of the Naphtha.—This has a very marked influence on the illuminating power of the naphthalised gas. In point of fact, I have ascertained, by experiment, not only that the different naphthas of commerce furnish different proportions of vapor to the gas, according to their different degrees of volatility, but also that those vapors are endowed with very different degrees of photogenic power. A single grain, for instance, of some of the hydrocarbons to

each cubic foot of common gas will raise its illuminating power to the extent of only about 1·69 per cent.; whereas, a grain of other hydrocarbons will raise it nearly 9 per cent. This is illustrated by the following table, where only a few of very many experiments are recorded:

TABLE *of the Specific Gravity, Boiling Point, Volatility, and Illuminating Power of the various Naphthas used in a common street carburettor, with a batswing burner consuming three feet of gas per hour.*

Specific gravity, water being 1000.	Boiling point (Centigrade.) (deg.)	Amount per cent. yielded by distillation.		Average quantity taken up by each foot of gas, (grains.)	Per centage increase of illuminating power.	
		Up to 130° Cent. (grains.)	From 130° to 150° Cent. (grains.)		Total.	For each grain of Naphtha per cubic foot.
698	63	86	14	20·1	33·9	1·69
676	40	98	2	34·4	62·1	1·80
869	102	76	22	12·1	40.8	3·37
827	115	56	40	6·5	21·7	3·43
808	117	27	53	6·1	21·0	3·60
852	128	4	51	3·8	14·2	3·72
869	107	75	19	9·2	34·9	3·79
869	103	83	14	11·8	46·8	3·96
816	119	15	45	3·4	14·4	4·23
856	114	23	49	4·4	18·9	4·29
814	105	60	34	7·0	33·5	4·78
865	124	9	34	3·3	15·8	4·79
845	90	92	8	12·0	65·3	5·44
874	119	45	37	4·8	26·7	5·56
879	93	92	8	9·5	53·2	5·60
870	129	5	44	2·8	15·7	5·61
862	121	10	45	3·3	20·4	6·16
848	97	77	15	10·2	68·4	6·70
861	117	24	29	2·3	18·8	8·17
875	110	75	20	6·9	60·8	8·81

It would seem from this, that a naphtha with a low specific gravity and a low boiling point is not well suited for the carburation of gas; for, although it yields a large quantity of vapor to the gas, the photogenic value of it is but small. This is the kind of naphtha obtained from the petroleums and shales of commerce, and it has not unfrequently been found in the naphthas supplied to the public lamps. On the other hand, the naphthas obtained from coal tar are much richer in carbon, and are, therefore, better suited for the carburation of gas. But the more volatile of these naphthas are so largely used in the manufacture of red and purple dyes, that it is difficult to obtain them, at a reasonable price, for the street carburettors. I have, therefore, been compelled to specify a quality of naphtha which is not well fitted for the manufacture of dyes; but this also is of a rather low volatility,

and is, therefore, not so good for the carburation of gas as it ought to be. The terms of the specification are, "that the naphtha shall be colorless; of a specific gravity of about 870; of a boiling point not higher than 110° C. (230° Fahr.); and yielding, on distillation, at least 70 per cent. of volatile naphtha, between the boiling point and 130° C. (266° Fahr.); and 20 per cent. between 130° and 150° C. (266° and 300° Fahr.)" This naphtha (the last in the table) furnishes about 7 gr. of hydrocarbon vapor to each cubic foot of gas, at ordinary temperatures, and it raises the illuminating power of the gas about 60 per cent.; in other words, it increases the light of a three-foot batswing burner from about seven candles to eleven, and thus makes three feet of gas of the same value as 4·8. If it were possible to obtain, at a reasonable price, a coal naphtha of a little higher volatility at ordinary temperatures—as, for example, a naphtha yielding about ten grains of hydrocarbon to each cubic foot of gas,—the illuminating power of the gas would be increased about 68 per cent. A gallon of this naphtha will weigh nearly 60,000 grains, and it would be sufficient to naphthalise 6000 cubic feet of gas—making them equal to about 10,000 feet of unnapthalised gas. Such a naphtha, even at 6s. per gallon, would be equal to just three times its money worth of gas; for a gallon of the naphtha costing 6s. would give the light of 4000 cubic feet of gas costing 18s. The only difficulty, at present, in the realisation of this object is, in the uncertain composition of the naphthas of commerce; but this difficulty would soon be overcome if a steady demand for such a naphtha existed. Even as it is, it may be said that the common coal naphthas of commerce increase the illuminating power of the London gas to the extent of about 4·5 per cent. for every grain of naphtha taken up by a cubic foot of gas. These naphthas are obtained at a maximum price of 4s. per gallon, and a gallon will double the illuminating power of rather more than 2600 cubic feet of gas; in other words, we have 4s. worth of naphtha doing the work of about 12s. worth of gas. These are the unquestionable results, not merely of laboratory investigations, but also of carefully conducted experiments at the public lamps in Moorgate Street.

As regards the time or duration of the Experiment.—As all the naphthas of commerce are mixtures of various hydrocarbons of different degrees of volatility, it happens that the most volatile constituents of the naphthas are given up very freely to the gas at the commencement of the experiment, and the less volatile with more difficulty at the end. In consequence of this, there is always a large increase of illuminating power when the carburettor is first charged with naphtha, and a marked diminution of it at last. This irregularity has not, hitherto, been compensated for by a regulated supply of gas; and, therefore, it has happened that when a naphtha yielding, at first, as much as twenty-three grains of hydrocarbon per cubic foot of gas has been used, the illuminating power has been doubled; but, after a time, from the diminished volatility of the naphtha, the power has gradually fallen to less than 25 per cent. Numerous experiments have been made to determine the influence of this circumstance on the value of the process, and the following table is given in illustration of it:

TABLE *showing the differences in the volatility of the Naphtha and the illuminating power of the gas, at different periods of the experiments.**

Quantity of gas passed, (cubic foot.)	Quantity of naptha taken up per foot of gas, (grains.)	Illuminating power in standard sperm candles.		
		Not carburetted.	Carburetted.	Increase per cent.
80	23·2	6·78	13·68	101·7
152	21·6	7·42	14·30	92·8
136	17·6	7·45	13·24	75·1
232	15·6	7·25	12·10	67·0
198	11·6	6·80	10·19	50·0
249	11·5	7·04	10·44	48·3
285	11·5	7·17	10·81	50·1
330	7·4	7·62	10·04	31·8
451	7·3	7·18	9·60	33·7
2113	12·1	7·21	11·60	60·1

The influence of temperature on the carburation of gas.—In the warm weather the volatility of the naphtha is increased, and, therefore, a larger amount of hydrocarbon vapor is given to the gas. A few experiments have been made, at different times of the year, on the street carburettors, with the view of ascertaining the extent of this influence within common ranges of temperature. The following are the results:

TABLE *showing the volatility of the Naphtha, and per centage amounts of increase of illuminating power, according to temperature, at different seasons of the year.*

Season.	Temperature, Fahrenheit.	Quantity of naphtha per cubic foot of gas, (grains.)	Per centage increase of illuminating power.
Spring, . . .	41°	5·25	23·6
Summer, . . .	72°	12·09	54·4
Autumn, . . .	62°	10·77	48·5
Winter, . . .	37°	4·94	22·2

These results show that it is of great importance to keep the carburettors at as uniform a temperature as possible; and it is with this view that the Carburetting Company have placed the apparatus within

* This experiment was made with a street carburettor of the form designed by me, and with 26,000 grains, or nearly four pints, of common naphtha, having a density of 869°, and a boiling point of 103° C., and yielding 82·7 per cent. of distilled product from its boiling point to 130° C., and 14·3 per cent. from 130° to 150° C. The experiment was continued for thirty days and nights, and the gas was continually burning from a three foot batswing burner, the temperature of the room being 22° C. (72° F.)

the lamps, thinking that, in such a situation, a common and uniform temperature of about 60° would be maintained. There is, however, a better situation at the top of the lamp, where the temperature, at the the time of carburation, would be very uniform at all seasons of the year, and where the apparatus would be entirely out of sight.

As regards the form of the apparatus.—Experiment has proved that the form of the apparatus has a very marked influence on the carburation of the gas; for when the instrument is so constructed that the gas merely passes into the chamber containing the naphtha, without sweeping over the surface of the liquid, a very small proportion of the volatile hydrocarbon is taken up. On the contrary, when the gas is brought into contact with a large surface of naphtha, it becomes highly charged with the vapor, and acquires a high illuminating power. In the course of the experiments which have been made for the purpose of estimating the value of this influence, four kinds of carburettors have been used, namely:

1. A single chamber, containing naphtha, with an inlet and exit pipe for the gas at the apex of the apparatus.
2. The carburettor supplied by the Carburetting Company, which is contrived to make the gas flow once over the surface of naphtha before it leaves the chamber.
3. A carburettor contrived by me, which has a series of septa for making the gas pass many times over the naphtha before it leaves the apparatus.
4. A carburettor of M. Mongruel, and also one of M. Nordhoff, both of which contain septa of cotton threads, saturated with naphtha, through which the gas must pass, and so become highly charged with vapor before it leaves the chamber.

In operating with each of these carburettors, under the same circumstances, and with the same naphtha, namely, that supplied according to the contract, it was found, that while the first form of apparatus gave only 3·2 grains of naphtha per cubic foot of gas, the second gave 6·0 grains, the third, 12·1 grains, and the fourth, from 22 to 23 grains. It is manifest, therefore, that to secure a uniform supply of hydrocarbon vapor, it is necessary to bring the gas into contact with a large surface of naphtha.

The quality of the gas affects the carburation.—When gas is already charged with a large proportion of the richer hydrocarbons, it manifests no disposition to take up the vapor of naphtha—on the contrary, if it be a cannel gas of very high illuminating power, the naphtha will deprive it, to a certain extent, of its hydrocarbons, and so render it weaker,—the process, therefore, is only applicable to such a poor gas as that which is supplied to the city; and, even in the case of this gas, it has been noticed that when a dose of naphtha has been already given to it, it does not show the same tendency to absorb the vapor as it did before.

The carburation of the gas is affected by the rate at which it traverses the apparatus.—This might be easily perceived from the circumstance that the longer and more completely the gas is brought into

contact with the naphtha, the more fully it becomes charged with its vapor. Experiment has shown that when in the same carburettor the gas is burnt at the rate of 3 feet per hour and the light is increased to the extent of 41 per cent., it will be only increased to 34 per cent. if it is burnt at the rate of $3\frac{1}{2}$ feet per hour; but this difficulty is easily overcome by increasing the surface of naphtha.

In concluson, therefore, it may be said, that although the success of the carburetting process is evidently dependent on many conditions, yet, as all these conditions are under control, there is no reason that they should not be at all times fulfilled, and the success of the process secured. One thing, it will be observed, is beyond all question, and that is, that every grain of common coal naphtha given to a cubic foot of gas increases its illuminating power about 4·5 per cent., (a good naphtha will increase it about 8 per cent.;) and this grain of naphtha costs only about one-third of its equivalent in London gas.

Nitro-glycerine.

We extract the following information in reference to this compound, which appears destined to play an important part in the arts, from the *Annales du Genie Civil:*

Nitro-glycerine is the product of the reaction which ensues when glycerine is slowly poured into a mixture of concentrated nitric acid, with twice its bulk of oil of vitrol. The glycerine loses three equivalents of water, which are replaced by three of nitric acid. It is called by its discoverers, *trinitrine*, *trinitro-glycerine*, *&c.*

It is a liquid of specific gravity 1·6, nearly insoluble in water, easily soluble in alcohol and ether. It has great stability and keeps indefinitely; foreign bodies do not favor its decomposition; at ordinary temperatures it even remains unchanged in presence of phosphorus and potassium. It does not explode by flame; burns by contact with an ignited body, but ceases to burn so soon as the contact is at an end. It explodes only at 360° Fahr. It detonates by a violent blow of a hammer, but only the part submitted to the blow explodes, without action on the surrounding liquid.

MM. Sombrero and Williamson first described the properties of this interesting liquid. M. A. Nobel first suggested its uses in blasting. In Sweden it has been used in place of gunpowder for more than six months. Its principal advantages are the following:

1st. Being insoluble in water and heavier than it, it can be used in wet mines or under water.

2d. Not exploding by contact of an ignited body unless strongly compressed, it may be carried, kept, and handled without danger.

3d. Its expansive force being ten times greater than gunpowder, it economizes labor.

4th. The rapidity of its explosion renders tamping of no importance, and thus renders the miner perfectly safe.

5th. It is as efficient in a soft and crumbling stone as in a hard and compact one. It leaves no residuum.

Notes on Magnesium. By ALONZO G. GRANT.

From the British Journal of Photography, No. 281.

It is with much diffidence that I attempt to communicate what little information I possess concerning magnesium and some of its appliances and recent developments. I cannot do better than commence with Sonstadt's patent, which consists of a cheaper and quicker method of separating and refining the metal from the magnesium limestone than formerly practised.

Apart from a knowledge of its existence as a scientific curiosity, my attention was first called to this comparatively new metal by Mr. Baldwin, who was engaged in making a few specimens of jewelry for Mr. Sonstadt, whose original idea, I believe, was that it would, to some extent, supersede silver. A few experiments soon put to rest that question, as it was found too soft and highly corrosive for ornamental purposes.

Magnesium next came before the public as a metal which ignited readily, and produced the highest quality of actinic light. As might have been expected, photographers were not slow to avail themselves of this property.

A lamp for the proper and regular combustion of the metal was next required, and I, in common with some others, have endeavored to supply that demand. That my efforts have been appreciated is apparent from the fact that my lamps have been in much request.

Although, by means of clockwork, I have succeeded in securing a steady and continuous light, yet the dense smoke emitted from the combustion of the metal has hitherto proved objectionable. I have partially succeeded in destroying the smoke and ashes by mechanically forcing them through diluted sulphuric acid, but as yet I have not applied this to the lamp, owing to the danger accompanying the use of acids.

The lamps have been used for assisting the action of daylight in the taking of portraits; and, in some cases, good artistic portraits have been taken by them without daylight. They have, too, been used in photographing the interior of the Pyramids of Egypt, copying the signatures of wills, &c.; and the latest application is the photographing of the sections of the interior of lead mines, to show the average quantity exposed, also the different kinds of veins which the miners are following. I have here a few specimens of this application, taken in the Wasses Mill-Close Mine, 140 yards deep, exhibiting the end of two pipe veins, and photographed to scale, showing a surface four feet by six feet.

There is something else which has recently been definitely settled by a series of experiments by T. W. Keats, Esq., F.C.S., and myself, and which show the penetrating visual power of the light to be as follows:

When the lamp is charged with four wires, weighing three grains each per foot, and the regulator is set to run out eight inches per

minute, the consumption, according to this is eight grains per minute, producing light without a reflector equal to 288 sperm candles, six to the pound, burning 576 grains of sperm per minute. Compared with London gas this is equal to 21¼ Argand burners, consuming 288 cubic inches of gas per minute, and by the use of a parabolic reflector the light is very much increased on any given point. One experiment has come to my knowledge in which a similar lamp was successfully used for signalling at a distance of 14 miles.

An important use of the lamp is its application to light-houses. It is also successfully used in Chadburn's opaque lantern for exhibiting colored photographs on a screen any size, reproducing all the colors.

Self-acting Pressure and Draft Regulator. By MM. MONTI, BONNETERRE, and ERHART.

In its simplest form, this apparatus is composed of a spiral copper tube, 0·8 inch in diameter, leading from the boiler into a condensation chamber, of the form of a truncated cone, and divided by an india rubber diaphragm. This arrangement is that used for pressure gauges. To the lower part of this chamber is attached a pump, whose piston carries a point which presses on a lever of the third order, whose long arm controls the register of the furnace, and is counter-weighed by an adjustible weight. The steam coming in by the copper tube undergoes condensation, and the upper part of the chamber fills with water under the pressure of the boiler. The counterpoise of the lever being adjusted to the maximum pressure allowed, if this pressure be exceeded the steam will press through the water and diaphragm upon the piston, whose point acting on the lever will close the register by a quantity proportioned to the increased pressure. The drafts being diminished, the pressure will fall, and the piston being drawn back the counterpoise will reopen the regulator. This ingenious device is said to have been adopted in several establishments in Paris, and to give an economy of from 10 to 15 per cent. in fuel. *Cosmos.*

New Green Avanturine Glass.

M. Pelouze recommends as a beautiful variety of ornamental glass one composed as follows: Sand, 250 parts; carbonate of soda, 100 parts; carbonate of lime, 50 parts; bichromate of potassa, 40 parts. This glass melts with perceptibly greater difficulty than that without the bichromate, is of a deep green color, and full of small spangles, crystals of oxide of chrome, which sparkle with a brilliancy inferior only to the diamond. As it resembles in character the Avanturine glass of Venice, M. Pelouze proposes for it the name of Chrome Avanturine. *Acad. Sciences, Paris.*

Electric Buoy.

M. Duchemin proposes to construct Ampêre's electric boat upon a sufficiently large scale, and to use it as a warning buoy on shoals, &c. He proposes to float, by means of cork, a carbon cylinder within a hollow cylinder of zinc, the connecting wire to be made to strike a bell in the usual way. He speaks of *small* cylinders, but gives no suggestion as to the size necessary to operate a bell large enough to be heard at any distance.

The Stereo-phantasmascope.

From the London British Journal of Photography, No. 280.

Perhaps the most expressive description of the reality of the scene which the stereoscope presents to our senses is conveyed in the brief but terse words of *The Times*—"Seems? nay, *is!*"

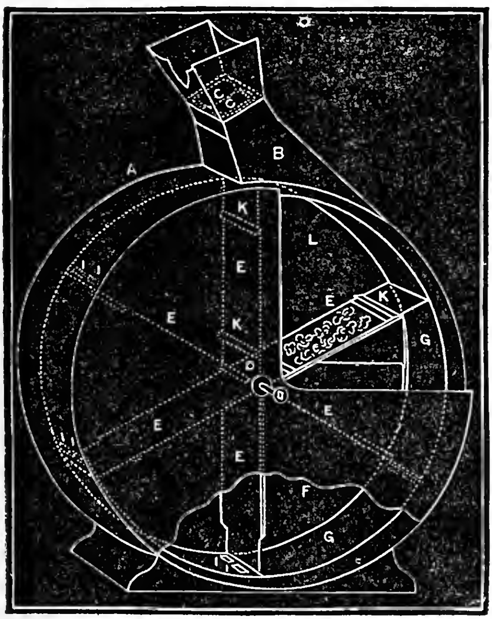
To increase still more the delusion under which, for the time being, a person labors while inspecting a stereoscope picture, attempts have been made to add to the already marvellous relief of the images in the stereoscope, the additional marvel of apparent motion. For several years binocular pictures have been vended in our bazaars and print-shops, in which the effect of motion is obtained in the following manner: If it be required to produce a reciprocating motion, such as a smith engaged in hammering a piece of metal, one view of the pair is taken with the hammer raised, and the other with it down upon the metal then being operated upon. So with sawyers at work; in one view the saw is up, in the other it is down. Other subjects of a similar nature will readily suggest themselves. To see these *in motion*, the most ready way is to wave between the eyes and the picture a piece of cardboard, or any similar material, which will have the effect of allowing only one picture to be seen at a time, when, on account of the *persistence of vision*, a stereoscopic image will be seen of an object in apparent motion.

In the cases which we have cited, the motion, it is obvious, will not be of a continuous nature, seeing that only the two extremes of the motion are represented. When more than two positions are to be depicted, some arrangement must be made by which each picture in succession can be presented to the eye.

There is a well known optical toy, the *phenakitiscope*, in which a series of pictures of the objects to be exhibited in motion are pasted on a disc, which is made to revolve, and the pictures on which are viewed through a slit. This instrument has been employed by our ingenious friends on the other side of the English Channel for the exhibition of "moving photographic images." The defects inherent in this method of viewing stereographs are very ably set forth in an interesting paper by M. Claudet read last week in one of the sections of the British Association, which will be found in the present number of the *Journal*, and to which we invite the attention of the reader.

It does not, however, appear to be generally known, that an instrument was invented and patented in America some years ago, by which the effects of either rotary or reciprocating motion can be exhibited in perfect stereoscopic relief. The instrument was, at the time of its invention, described by Mr. Coleman Sellers, of whose fertile brain it is the offspring; yet, seeing that the subject has been deemed worthy of being brought before the notice of the British Association, an apology is hardly required for again reviving the subject, and giving a description of Mr. Seller's *phantasmascope*, by means of which we have seen, in all the stereoscopic relief of nature, a mill wheel majestically revolving with beautiful regularity.

One form of phantasmascope consists of a cylinder D, not more than an inch in diameter, around which are arranged six wings, E E, like the paddles of a water-wheel, and on these wings the stereographs are fixed.



Around the outside of these wings passes a band of tin, G, four inches wide, through which are cut slits, I I, each a quarter of an inch wide and an inch long, the centre of each pair of slits being three inches apart. These slits are close to each of the wings and immediately at the back of each picture, so that through the slits may be seen the picture on the face of the next wing. The ordinary stereoscopic prisms placed at C C combine the pictures as they pass in succession before the eye. The whole of each picture cannot be seen at one time, but according to whether it is turned to or from the observer, so the picture is seen at its lower or upper edge first, and then the vision passes over the card, which has scarcely gone before another is presented to the view. On account of the "persistence of vision" the pauses between the pictures are not perceived.

By the instrument which we have just described, the most wonderful effects of combined motion and relief are obtained; and we are glad of this opportunity of again calling attention to the ingenious and, perhaps, partially forgotten phantasmascope of our friend, Mr. Sellers, and of testifying to the ingenuity displayed in this interesting instrument.

Another new Process of Engraving.

From the London Builder, No. 1159.

A layer of finely pulverized chalk is compressed and smoothed by hydraulic power on a metal plate. The artist draws on this with an ink which makes the lines hard. A soft brush or a piece of velvet rubbed over the plate leaves the inky portion in relief. The whole plate is then saturated with a chemical solution, which turns the chalk into stone, somewhat analogous to Ransome's principle seemingly. From this, impressions may be taken, or stereotypes or electrotypes obtained. The cost of these "graphotypes" is said to be something like one-tenth the cost of wood-blocks, to which the *Morning Herald* says they are fully equal; but whether this process be likely to come to anything practical, or whether it is to follow so many others into oblivion, we cannot yet say; surely something useful will come of all these inventions at last.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, November 15*th*, 1865.

The meeting was called to order with the President, Mr. Wm. Sellers, in the chair.

The minutes of the last meeting were read and approved. The minutes of the Board of Managers were reported, including the following donations to the library: From the Chemical Society, the Statistical Society, the Society of Arts, and the Royal Geographical Society, London; the Natural History Society, Montreal, Canada; Young Men's Association, Milwaukie, Wisconsin; the Commissioner of Agriculture, Washington, D. C.; the Legislature of Pennsylvania; the Schuylkill Navigation Company, Wm. Biddle, and Prof. John F. Frazer, Philadelphia.

The minutes of the various Standing Committees were reported.

The Special Committee on experiments in steam expansion, reported progress.

The Report of the Secretary on new discoveries and inventions, &c., was then read as follows:

Secretary's Report.

Engineering Works.—The tunnel for supplying Chicago with water from Lake Michigan is making steady and rapid progress, the average rate being 12 feet per day. The cribs for the inlet pier, about two miles out from shore, have been successfully placed, and the iron tubing for the descending shaft at that point is in a finished state.

The Barmouth viaduct, crossing the mouth of the river Maw, North Wales, is a work of considerable extent now in course of construction. Its length is one mile; 770 yards consists of a solid embankment, 740 are of timber, divided into 117 spans of 19 feet each, 109 yards of iron, divided into 7 spans of 40 feet each, and one of 47 feet.

It appears from a paper read before the Mechanical Section of the British Association, during their late meeting at Birmingham, that a coal-cutting machine worked by compressed air has been successfully operated in a colliery (the Blaina works) upon coal of a very refractory and unpromising character. Its rate of cutting is 8 yards per hour, 3 feet deep. The great advantage of compressed air, as a motor for such machines, is its effect upon the ventilation of the mine, while its great drawback is the loss of power consequent upon the loss of the heat developed by the compression, which is largely abstracted before the air reaches the scene of its labors.

A regulating stopcock for use with burning gas and fluids generally, invented by G. G. Percival, of this city, has been this evening submitted to your notice. Its novel feature consists in the insertion of a set screw into a lug on the barrel of the cock, which arrests the motion of the lug which has a pin or plug attached to it in the manner already generally used. By turning this set screw, its projection through the lug is altered so that it arrests the motion of the plug at a different point, and thus the opening of the cock may be regulated.

This is of consequence, 1st. In public buildings, where the lowering of the lights with a common cock is a matter of great difficulty.

2d. In hotels, and even in private houses, waste of gas often occurs from turning the cock too far. This is rendered impossible in this cock by so arranging the set screw that it can only be turned by a key in the possession of the proprietor, or other responsible person, the movement of the cock being then limited by a proper adjustment, cannot be made to exceed this bound by any one else.

3d. Where consumption of gas is calculated by the "average meter system," this contrivance furnishes an easy means of adjusting different burners to a proper average.

Chemistry.—An improvement in the process for extracting precious metals from their ores by amalgamation has been introduced by Professor Crooks, the discoverer of thalium, and the editor of the *Chemical News.*

This consists in the addition of a very small quantity of sodium to the mercury. By this means, its power of extracting the valuable metal is increased, first, we believe, because its cohesion is decreased, making adhesion to other bodies easier; second, because the strong chemical affinites of the sodium for common impurities keep these from the mercury; and, lastly, because the attraction of this and like amalgams for metals is very strong. Thus we have often noticed the tenacity with which a sodium or potassium amalgam will adhere to the blade of a penknife when preparing this mixture for the development of the ammoniacal amalgam; and with this last substance have even made iron filings into a consistent ball.

From a paper read before the British Association, by Dr. D. S. Price, we learn that the blackening effect produced on lead paint by sulphuretted hydrogen may be counteracted or removed by free exposure to sunlight.

Contact with sodium or potassium causes instantaneously the explo-

sion of gun-cotton, according to Mr. W. S. Scott, in a paper read before the British Association at their last meeting. We would call attention to the methods of printing (mechanically) photographs, invented by Messrs. Walter Woodbury and J. W. Swan, independently, which form the subject of an interesting paper, in the Mechanics' Magazine, for September, page 194.

Messrs. Paul and Ernest Depouilly have published a new method of obtaining benzoic acid from naphthaline. The naphthaline is oxidized into phtalic acid; this is combined with lime to form a neutral salt; this is then mixed with an additional equivalent of lime, and heated to 626° or 662° for ten hours in iron cylinders which are immersed in a bath of lead.

A platinum medal has been awarded by the Parisian Society for the Encouragement of Industry to M. Ozouf, a celebrated manufacturer of soda and other effervescent waters, for a process by which pure carbonic acid may be readily supplied. Coke being burned in an appropriate furnace, the carbonic acid generated is absorbed in a solution of carbonate of soda, which is thus converted into bicarbonate. By heating this, the second equivalent of $C\,O_2$ is disengaged, and the solution is then ready for a fresh dose of the gas.

Another substitute for india rubber has made its appearance under the name of Parkesine, which is prepared as follows: Gun-cotton is dissolved in wood naphtha and mixed with oil or resin; it is then vulcanized by use of chloride of sulphur, and may be readily colored by the aniline dyes. Many beautiful specimens of this substance were exhibited at a late soirée of the British Association. We should think that the cost of the materials used would prevent any general application of this compound.

Mr. R. W. Artlett has been experimenting largely with the process for preparation of oxygen from hypochlorite of lime, (CaO, ClO,) mentioned a few months since, and finds that oxides of copper and iron act like that of cobalt in liberating the oxygen from the lime salt. A few drops of nitrate of copper will serve for this purpose.

Another process for oxygen is announced by a M. Carlevaris. This consists in heating together black oxide of manganese and silica, ($MnO_2 + SiO_3$,) when silicate of manganese is formed, and one equivalent of oxygen set free, (MnO, $SiO_3 + 0$.)

The equivalent of niobium has lately been determined by Deville and by Blomstrand; the former makes it 47 or 48·3, the latter 39.

Night photography having been introduced by means of magnesium, seems to be extending its range of applications, with other bodies. By burning $\frac{1}{4}$ of a pound of a mixture containing phosphorus and nitre, which continued its combustion six minutes, a Mr. Wilkinson, of Chelsea, succeeded in taking a picture of a windmill at the foot of his garden, and even found the neighboring houses to "come up" with great sharpness.

Photographs of the interior of a lead mine have been successfully taken in England by Mr. Alonzo Grant. One in the Wasses Mill-Close Mine, shows two pipe veins and the surrounding surface over an area of 4 by 6 feet.

The photographing of the interior of the Pyramids, by Prof. Piazzi Smith, has not proved successful in an artistic point of view, on account of the extremely vitiated state of the air within the close passages constantly visited by travelers with numerous torches and candles, by reason of which the magnesium wire burned with much impaired brilliancy. Some limited views, sufficing however to establish disputed measurements, were taken, though only one picture could be obtained within twenty-four hours, the magnesia smoke requiring this time to settle. A mixture of magnesium filings and mealed powder was said to produce a better effect than the wire.

The following comparison of the magnesium wire with other sources of light is of interest. Four wires weighing three grains per foot, each burning at the rate of eight inches per minute, or eight grains in that time, give a light equal to 288 sperm candles, or $21\frac{1}{4}$ Argand gas-burners. At this rate of consumption one ounce of wire, costing \$6·50 would last one hour.

British Journal of Photography.—A curious French toy has lately been exciting much attention. It is called the egg of Pharaoh's serpent, and consists of sulpho-cyanide of mercury made into a little conical pellet like a pastel. This being ignited, burns with a blue flame giving out a long coil of a consistent material resembling a snake in its length and convolutions, and seemingly a hundred times larger than its parent egg.

Professor John F. Frazer here showed the operation of some of these serpent eggs, prepared by the Messrs. Wyeth, and explained their action, as, also, the history of the substance mellon which is the bulky product of their combustion.

Mr. Coleman Sellers showed some others made by Messrs. Bullock & Crenshaw.

The meeting was then, on motion, adjourned.

H. Morton, *Secretary.*

BIBLIOGRAPHICAL NOTICE.

The Practical Entomologist. A monthly bulletin published by the Entomological Society of Philadelphia, for gratuitous distribution among farmers and agriculturists.

A very neatly printed journal, apparently devoted to the distribution of information on the subject of insects noxious and useful (?) to plants and farmers.

We do not doubt the value of the knowledge thus disseminated, and we believe that the gratuitous distribution by the Society may carry it where it will be useful. At all events, we are glad to see this indication of health and energy in this young Society.

ERRATA.

Page 351, line 6 from top, for "inclends," read "materials."

A Comparison of some of the Meteorological Phenomena of OCTOBER, 1865, *with those of* OCTOBER, 1864, *and of the same month for* FIFTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 11¼′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

	October, 1865.	October, 1864.	October, for 15 years.
Thermometer—Highest—degree, .	78·00°	75·00°	90·00°
" " date, .	10th.	6th.	4th, '58.
" Warmest day—mean,	73·17	71·50	78·30
" " " date,	10th.	6th.	6th, '61.
" Lowest—degree, .	37·00	36·00	28·00
" " date, .	25th.	10th.	25th, '56.
" Coldest day—mean,	44·83	44·83	35·80
" " " date, .	25th.	22d.	27th, '59.
" Mean daily oscillation,	11·23	13·16	15·28
" " " range, .	5·13	4·56	5·41
" Means at 7 A. M., .	52·55	50·11	51·28
" " 2 P. M., .	60·15	59·37	62·84
" " 9 P. M., .	54·85	53·18	55·31
" " for the month,	55·85	54·22	56·48
Barometer—Highest—inches, .	30·225 ins.	30·022 ins.	30·452 ins.
" " date, . .	30th.	2d.	25th, '61.
" Greatest mean daily press.	30·209	30·015	30·378
" " date, . .	30th.	3d.	25th, '61.
" Lowest—inches, . .	29·155	29·218	29·012
" " date, . .	15th.	28th.	26th, '57.
" Least mean daily press.,	29·226	29·294	29·059
" " date, . .	19th.	28th.	26th, '57.
" Mean daily range, .	0·171	0·129	0·144
" Means at 7 A. M., .	29·778	29·715	29·9[illegible]6
" " 2 P. M., .	29·746	29·674	29·865
" " 9 P. M., .	29·786	29·726	29·892
" " for the month, .	29·770	29·705	29·888
Force of Vapor—Greatest—inches,	0·527 in.	0·703 in.	0·731 in.
" " " date, .	11th.	6th.	7th, '61.
" " Least—inches, .	·132	·138	·065
" " " date, .	29th.	9th.	21st, '59.
" " Means at 7 A. M., .	·293	·278	·314
" " " 2 P. M., .	·281	·285	·340
" " " 9 P. M., .	·298	·300	·323
" " " for the month,	·291	·288	·326
Relative Humidity—Greatest—per ct.,	94·0 per ct.	91·0 per ct.	97·0 per ct.
" " " date,	18th.	2d.	often.
" " Least—per ct.,	34·0	36·0	23·0
" " " date, .	29th.	14th.	21st, '59.
" " Means at 7 A. M.,	70·5	72·7	77·7
" " " 2 P. M.,	51·7	53·9	56·1
" " " 9 P. M.,	66·5	70·6	72·9
" " " for the month	62·9	65·8	68·9
Clouds—Number of clear days,* .	11	12	9·7
" " cloudy days, .	20	19	21·3
" Means of sky cov'd at 7 A. M.,	51·0 per ct.	54·8 per ct.	56·3 per ct.
" " " " 2 P. M.,	57·1	64·8	55·7
" " " " 9 P. M.,	38·1	34·5	39·8
" " " for the month	48·7	51·4	50·6
Rain—Amount,	3·358 ins.	1·727 ins.	2·888 ins.
No. of days on which Rain fell,	6	8	8·8
Prevailing Winds—Times in 1000,	N77°35′W ·293	N82°34′W ·276	N74°12′W ·242

* Sky one-third or less covered at the hours of observation.

INDEX.

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